JOURNAL OF THE A·I·E·E·

SEPTEMBER 1928

AIEE

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

MEETINGS

of the

American Institute of Electrical Engineers

ATLANTA REGIONAL MEETING, Southern District No. 4, October 29-31, 1928, Atlanta, Georgia

WINTER CONVENTION, New York, N. Y., January 28-February 1, 1929

CINCINNATI REGIONAL MEETING, Middle Eastern District No. 2, at Cincinnati, Ohio, March, 1929

MEETINGS OF OTHER SOCIETIES

Institute of Radio Engineers, Engineering Societies Building, New York, N. Y., Sept. 5

Illuminating Engineering Society, King Edward Hotel, Toronto, Can., Sept. 17-20 (L. H. Graves, 29 West 39th Street, New York, N. Y.)

National Electric Light Association

Rocky Mountain Division, Hotel Colorado, Glenwood Springs, Colo. Sept. 17-20

New England Section, South Poland Springs, Maine, Sept. 24-27

Great Lakes Section, French Lick Springs, Ind., Sept. 27-29

Kansas Section. Wachita, Kan., October 18-19

American Electrochemical Society, Charleston, W. Va. (C. G. Fink, Columbia University, New York)

American Electric Railway Association, Cleveland, O., Sept. 22-28 (J. W. Welsh, 292 Madison Ave., New York)

International Committee on Illumination, Saranac Inn, Lake Saranac, New York, Sept. 22-28 (See Illuminating Engineering Society)

The American Society of Mechanical Engineers, Boston, Mass., Oct. 1-3 (C. W. Rice, 29 W. 39th Street, New York, N. Y.)

National Safety Council, Hotel Pennsylvania, New York, N. Y., October 2-5 (W. H. Cameron, 108 East Ohio Street, Chicago)

American Welding Society, Philadelphia, Pa., Oct. 8-13 (M. M. Kelly, 33 W. 39th St., New York, N. Y.)

JOURNAL

OF THE

American Institute of Electrical Engineers

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street, New York

PUBLICATION COMMITTEE

E. B. Meyer, *Chairman*, H. P. Charlesworth, F. L. Hutchinson, Donald McNicol, L. F. Morehouse

George R. Metcalfe, *Editor*

Changes of advertising copy should reach Institute headquarters by the 15th day of the month for the issue of the following month.
Subscription: $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Philippines, $10.50 to Canada and $11.00 to all other countries. Single copies $1.00.
Entered as matter of the second class at the Post Office, New York, N. Y., May 10, 1905, under the Act of Congress, March 3, 1879.
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on August 3, 1918.

Vol. XLVII — SEPTEMBER 1928 — Number 9

TABLE OF CONTENTS

Papers, Discussions, Reports, Etc.

Institute and Related Activities

A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address be sure to mention the old one, indicating also any changes in business connections.

(The Journal of the A. I. E. E. is indexed in Industrial Arts Index.)

Current Electrical Articles Published by Other Societies

Engineers & Engineering, June 1928

Arc Welded Steel Buildings at West Philadelphia Works of the General Electric, by F. P. McKibben

Proceedings Institute of Radio Engineers, August 1928

A New Type of Standard Frequency Piezo-Electric Oscillator, by L. P. Wheeler and W. E. Bower

The Effect of Regeneration on the Received Signal Strength, by Balth. van der Pol

Characteristics of Output Transformers, by J. M. Thomson

Notes on Quartz Plates, Air-Gap Effect, and Audio-Frequency Generation, by August Hund

Notes on Aperiodic Amplification and Application to the Study of Atmospherics, by August Hund

Effect of the Antenna in Tuning Radio Receivers and Methods of Compensating for It, by Sylvan Harris

The Cause and Prevention of Hum in Receiving Tubes Employing Alternating Current Direct on the Filament, by W. J. Kimmel

The International Union of Scientific Radio-Telegraphy, by J. H. Dellinger

The Tuned-Grid, Tuned-Plate, Self-Oscillating Vacuum-Tube Circuit, by J. Warren Wright

Radiation and Induction, by R. R. Ramsey and Robt. Dreisback

Development of a System of Line Power for Radio, by G. B. Crouse

Iron & Steel Engineer, June 1928

Yearly Review of Electrical Developments in Iron and Steel Industry, by W. H. Burr

Selection of Motors for Main Drives of Merchant, Bar, and Rod Mills, by C. B. Houston

Report of Committee on Electric Heat, by G. H. Schaeffer

Rules and Regulations Pertaining to Operation of a Steel Plant High-Tension System, by R. M. Hussey

JOURNAL OF THE A. I. E. E.

DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

Vol. XLVII SEPTEMBER, 1928 Number 9

A MESSAGE FROM THE PRESIDENT

The Inspiration to Committee Work

WORK on Institute committees is well worth while.

Anyone who heard the reports of the technical committees as they were presented at the recent Denver Convention or who has had occasion to read these reports must have been impressed by the wealth of information contained in them and by their evidence of painstaking work on the part of the committees. It is probably appreciated by comparatively few outside of committee circles how effectively this work influences the progress of the profession and of the many industries depending on the profession.

These committees not only strive to present a comprehensive picture of the important advances during the year in their special fields but they aid in advancing the art along such special lines as seem most desirable in the light of the experience of their members. Advancing the art is accomplished by arranging for the presentation of suitable papers and discussions and, in some instances, by directing research. In addition, the Meetings and Papers Committee refers to these committees for review and recommendation papers independently submitted for Institute meetings and related to the field covered by the committees.

The effectiveness of the results obtained depends on the guiding ability of the chairman and on the knowledge, ability and vision possessed by the committee members.

The president, who is charged with the appointment of these committees, cannot have the complete knowledge of the Institute membership that would be necessary to insure getting all the available talent into committee activity. With the advice of the selected chairmen he does the best he can to get a well balanced committee but unavoidably there will remain many who are not called who could and would serve with profit to all—and the Institute is the loser. How to improve this condition is a problem to which the members could well give some thought.

Appointment to serve on a committee is a recognition of ability. It is a distinct honor but he who accepts it takes upon himself an obligation which can be repaid only by an honest effort at active participation. This obligation carries with it much inspiration. The greatest joy in life lies in service, and what service could be happier than that for one's profession and along the line of one's greatest daily interest. And there are other rewards beyond the satisfaction of real service. These come from the friendships formed and the broadening of outlook resulting from committee contacts.

Committee service helps to make men grow in their profession and in other ways.

The record of an engineer's committee activities can well be taken as part measure of his contributions to his fellows.

R. F. Schuchardt

Some Leaders of the A. I. E. E.

Henry H. Humphrey, vice-president of the Institute 1906-1908 was born June 23, 1862, at Coolville, Ohio, and was graduated from Ohio University, Athens, Ohio, in 1884 with the degree of A. B. The following year he took post-graduate work in electrical engineering at Cornell; in 1886 he received the degree of M. S. from that college. The summer vacations of 1884 and 1885 were spent on United States Coast and Geodetic Survey work in southern Ohio.

In 1886 and part of the following year, Mr. Humphrey was on the staff of Westinghouse, Church, Kerr & Co., as construction engineer, during which service he was assistant engineer in connection with the installation of the a-c. central station at Carbondale, Pa.,—the second a-c. central station plant started in this country,—and took part in erecting the experimental plant for the Hoosac Tunnel at North Adams, Mass. In 1888 he became superintendent of the Buffalo Light & Power Company, Buffalo, N. Y., and later, superintendent of the Brush Electric Light Company of the same city. Resigning from the latter position in 1900 because of ill health, he engaged in the engineering and contracting business in Omaha for about a year.

During 1891 he was the agent of the Edison General Electric Company at St. Louis, and St. Louis manager for the General Electric Company during the 1892. In 1893, as engineer and salesman of the St. Louis Electrical Supply Company, Mr. Humphrey had charge of the installation of all the electrical work on the "Midway" at the Chicago World's Fair. In 1894 and 1895 he was engineer and sales agent for the Laclede Power Company of St. Louis, and from 1896 to 1900 was engaged in consulting work as a member of the firm of Bryan & Humphrey. During this latter period, his most important work was the construction of the plant of the Imperial Electric Light, Heat and Power Company of St. Louis, all the electrical work being under his direct charge.

From 1900 to 1917 he was engaged in consulting mechanical and electrical engineering work, with offices in the Chemical Building, St. Louis. During this time, his most important work, perhaps, was the design of a complete electrical and mechanical plant for the De Beers Explosive Works, at Capetown, South Africa. Bids were received for this work both in Europe and America, and all bids sent to Mr. Humphrey for analysis and report with recommendation for award of contract; all superintendence of actual work was done by the company's engineers on the ground. His work has been done not only in isolated plants, department stores, hotels and office buildings in the East, but has extended into Texas and Mexico and as far west as Salt Lake City and Vancouver, British Columbia. His largest isolated plant design was the complete electrical and mechanical equipment of the Railway Exchange Building in St. Louis. Perhaps his best outside plant work was on the Columbia Water and Light Company at Columbia, Mo., in which he was associated with Professor H. B. Shaw, Dean of the Engineering Department of the University of Missouri.

During the years 1917 to 1920, as vice-president and treasurer of the Flad-Humphrey Engineering Company, he worked closely with Mr. Edward Flad, who at the time, was a member of the Public Service Commission of the State of Missouri and is now a member of the Mississippi River Commission. He is the son of the distinguished St. Louis Engineer, Henry Flad.

Since 1920 Mr. Humphrey has been in general consulting electrical and mechanical engineering practise in St. Louis. During the year 1906, he was vice-president, manager, and consulting engineer of the Jefferson City Light, Heat, and Power Company of Jefferson City, Mo., rebuilding and enlarging its gas and electric plant during that time. At the time of the International Electric Congress during the World's Fair in St. Louis in 1904, he served as chairman of the Local Committee of Organization and after the Congress, preserved all of the unused copies of the papers to furnish to applicants in various parts of the world, keeping them together for this purpose for the following year.

From time to time Mr. Humphrey has read papers before the Engineers Club of St. Louis and frequently contributed articles to technical publications. He has been a member of the Institute since 1896 when he became an Associate. He was transferred to the grade of Fellow in 1913. He is a member of the St. Louis Institute of Consulting Engineers, St. Louis Electrical Board of Trade, St. Louis Hospital Saturday and Sunday Association and of the Masonic Order, also a Senior Member of the Engineers Club of St. Louis, and a member of the Circle Club, and of the Amateur Athletic Association.

Radio Aids to Air Navigation

Research work extending over two years has resulted in the development and practical demonstration of radio aids to flying on the civil airways. These aids comprise a radio-beacon system marking out definite courses and radiotelephone service from ground to airplane. The whole system can be utilized by airplanes carrying no radio apparatus except a simple receiving set. This development, which was carried on by the Bureau of Standards for the Aeronautics Branch of the Department of Commerce, was briefly described on page 19 of the Radio Service Bulletin of March 31, 1928. A technical description of the work, *Development of radio aids to air navigation*, by J. H. Dellinger and Haraden Pratt, was published in the July, 1928 *Proceedings* of the Institute of Radio Engineers, page 890.

In the same issue of the *Proceedings*, page 985, there is given a *Bibliography on aircraft radio*, by C. B. Joliffe and Elizabeth Zandonini. This bibliography includes 257 references to foreign and domestic periodicals.—*Technical News Bulletin.*

Abridgment of

Transmission Experience of the Public Service Company of Colorado

BY M. S. COOVER[1]
Associate, A. I. E. E.

and

W. D. HARDAWAY[2]
Associate, A. I. E. E

Synopsis.—*The 100,000-volt transmission lines of the Public Service Company of Colorado, which were completed in 1909, extended from the Shoshone hydro plant on the Colorado River across the Continental Divide to Denver and represent pioneering in high-voltage transmission at high altitudes. This combination of factors, coupled with a rapid expansion of the whole system in recent years, called for the satisfactory solution of many problems. The paper describes the system in a general way, and outlines some of the more salient operating difficulties that have arisen from time to time, as well as their remedies. Brief mention is also made of the method of load dispatching.*

* * * * *

Introduction

THE purpose of this paper is to submit the results of several years' experience in operating the high-voltage network of the Public Service Company of Colorado.

A part of the transmission lines included in the present network operated by the company has been in continuous service for 20 years. Two years following this initial construction, the line was extended to a total length of 153.5 mi., from the Shoshone hydro plant on the Colorado River near Glenwood Springs across the Continental Divide to Denver, and from Denver to the Boulder hydro plant. Other sections of the network have been constructed during the past four years. With the exception of the transformers at the Shoshone hydro plant which were rebuilt last year, all of the original transformers and oil circuit breakers are still in service. This not only represents pioneering in the field of high-voltage transmission, but also progress in the art of design, construction, and operation. It is hoped that the data herein submitted will add to the information now available on such operating experience; also, that it may prove to be of some value to those having similar operating and maintenance problems.

Description of System

The company serves the electric lighting and power requirements of practically all of the central, north central, and northeastern portions of Colorado, which area covers approximately 750 sq. mi. and includes about 116,300 customers.

The high-voltage system comprises a total of 518 mi. of line at altitudes ranging from 5280 ft. to 13,700 ft. above sea level with 217 mi. of line operated at 100,000 volts and 301 mi. of line at 44,000 volts. The properties are segregated into what is known as the central system and the outside system, there being at present no means of interconnecting these two groups. Transmission in the central system is over 217 mi. of line at 100,000 volts and 181 mi. of 44,000 volts, and in the outside system transmission is all at 44,000 volts over 120 mi. of line.

The generating plants connected to the central system, their capacity and type of motive power, are listed in Table I, while those of the outside system are listed in Table II. Since the outside system comprises only a small portion of the total properties operated

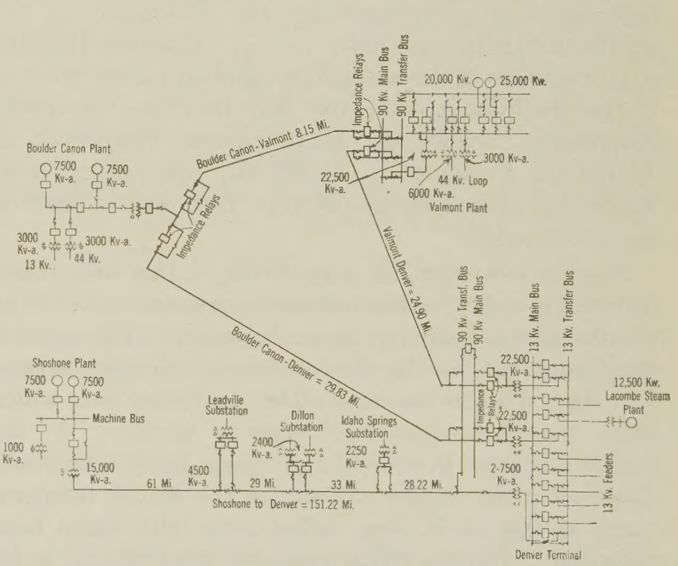

Fig. 2—Simplified Diagram of the 100-Kv. Lines of the Public Service Company of Colorado

by the company, the remaining material submitted in this paper will be confined entirely to the 100,000-volt transmission lines of the central system, a simplified diagram of which is given in Fig. 2.

The 100,000-volt loop is equipped with impedance type protective relays, which have given correct sectionalization for about 95 per cent of the flashovers. Until recently, flashovers on the Shoshone line have been cleared by manually lowering generator voltage. In October, 1927 automatic equipment was installed for

1. Assoc. Professor E. E., University of Colo, Boulder, Colo.
2. Supt. Hydro Production & Transmission, Public Service Co. of Colo., Denver, Colo.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

lowering generator voltage by inserting a large block of resistance in the generator field circuit.

The switching center of the central system is the Denver terminal substation, located two miles within the city limits of Denver. Three 100,000-volt lines converge there, and 60,000 kv-a. in transformer capacity is provided for supplying 13-kv. city feeders. The system operating and dispatching offices are located at this substation. Private telegraph and telephone and leased telephone lines are provided for communication with all parts of the central system.

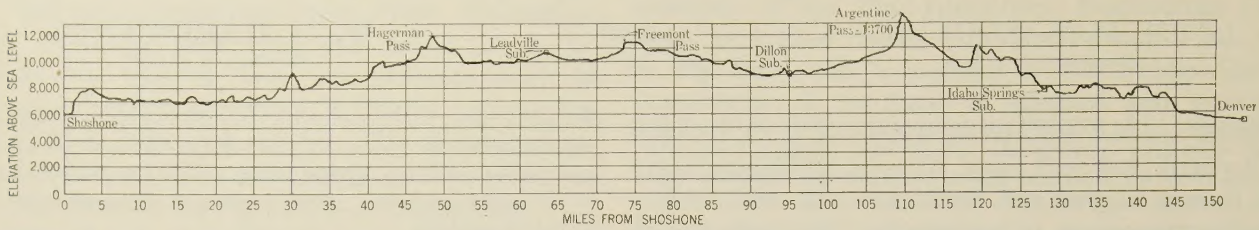

Fig. 3—Profile of Transmission Line, Shoshone to Denver; Denver to Boulder

Altitude—Weather Conditions

The 100,000-volt line which crosses the Continental Divide presents a most difficult task of maintaining a high degree of continuous service. Reference to the profile of this line as shown in Fig. 3 discloses that the line originates at an altitude of approximately 6000 ft. at the Shoshone hydro plant; then traverses the Rocky Mountains, negotiating three passes—Hagerman at 12,000 ft., Freemont at 11,500 ft., and Argentine at 13,700 ft.; thence to the Denver Terminal at 5280 ft. above sea level.

Shortly following the completion of this line, many interesting experiments were conducted and some of the results have appeared in Institute papers. The weather conditions during the winter season are very severe, making it difficult to secure all the operating data which often would be desired in cases of trouble. At the higher altitudes, in the fall and spring, there is an abundance of moist winds, whereas in the winter temperatures as low as 52 deg. below zero fahr. have been recorded. The maximum measured wind velocity so far reported is 165 mi. per hour. These conditions, combined with the heavy snows, make certain sections of the line almost inaccessible for a period of time, which means that the line must be thoroughly dependable from both the electrical and mechanical standpoint.

Covering an average period of 130 days per year, considerable lightning was encountered on this line. Many statements are made to the effect that insulation is the foundation of the electric power system; and true it is; yet any line exposed to storms, lightning, and slides, as previously mentioned, calls for a high degree of sturdiness in both electrical and mechanical design. The line across the Continental Divide has been in operation sufficiently long to permit a satisfactory solution to most of the mechanical problems in maintenance, but the problem of protection against lightning is still a very difficult one to master reasonably.

TABLE I.
GENERATING PLANTS—CENTRAL SYSTEM

Location	Rated kw. at 0.8 p. f.	No. of units	Motive power
Shoshone	14,400	2	Water
Boulder Canyon	14,400	2	Water
Georgetown	900	2	Water
Leadville	1,925	2	Steam
Lafayette	6,000	4	Steam
Denver (West Plant)	9,250	4	Steam
Denver (Lacombe Plant)	16,500	3	Steam
Valmont	45,000	2	Steam

TABLE II
GENERATING PLANTS—OUTSIDE SYSTEMS

Location	Rated kw. at 0.8 p. f.	No. of units	Motive power
Cheyenne	4,000	4	Steam
Sterling	2,250	3	Steam
Alamosa	1,400	2	Steam
Salida	700	2	Steam
Salida	1,200	5	Water

Line Insulation

The original insulation was four Hewlett disk insulators on both dead-end and suspension strings, with a 7½-in. spacing of disks on the dead-end and 6-in. spacing on the suspension strings. The ratio of dead-ends to suspensions was about one to fifteen. Two ¼-in. steel ground wires were put up for protection. Many difficulties were encountered during the first year of operation, principally on account of the lines being under-insulated and on account of mechanical failures of the ground wires. During the following year, the ground wires were removed, and a fifth disk was added to all dead-ends. This measure showed some improvement in service. During the following year arc points were placed on both ends of all strings to provide a flashover path which did not destroy insulators. They do not, however, reduce the number of outages caused by lightning.

In 1916, it was decided that the flashovers per annum were still too numerous, whereupon a fifth disk was added to all suspension strings and a sixth disk to all dead-ends. This reduced the number of flashovers approximately 75 per cent.

New 100-Kv. Lines

The Valmont-Denver line and the Valmont-Boulder

line (see Fig. 2) were built during 1924, and placed in service during December of that year, which also marked the completion of the first unit of the new Valmont steam plant. These two lines tie in the plant with the Denver Terminal and with the Boulder Canyon hydro plant. American Bridge Company towers were purchased for both lines and designed for single-circuit horizontal conductor spacing on the Valmont-Boulder tie, (see Fig. 6), while twin circuit vertical conductor spacing is used on the Valmont-Denver tie. Only one circuit was strung on the latter tie, and the second circuit will be added when the growth in load reaches such a point as to demand it.

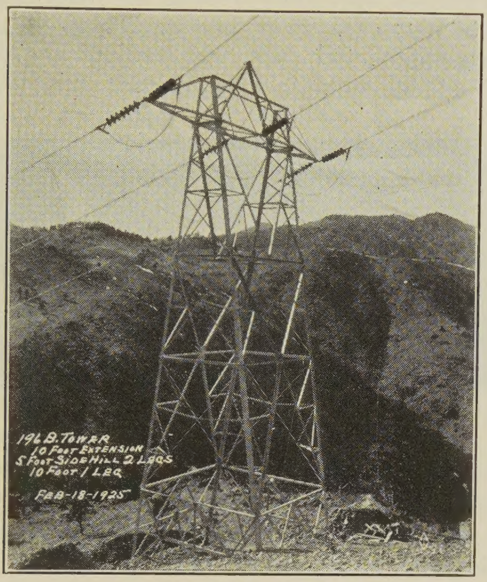

Fig. 6—Type of Tower used on Valmont—Boulder Line

High mechanical strength, 336,000-cir. mil A. C. S. R. conductors are used on both tie lines, the cable being made up of 30 strands of aluminum 0.1059 in. in diameter and 7 strands of steel 0.1059 in. in diameter. All suspension strings consist of seven No. 25622 O-B insulators spaced 4¾ in., and all dead-end strings consists of seven No. 26240 O-B insulators spaced 7 in. Arc points were initially placed on suspension clamps and at dead-end points on all strings, hoping to avoid breakage of upper disks by flashovers.

Ground Wires

Before going into a discussion of the interruptions to service on the 100,000-volt lines, it would be well to review the company's experience with ground wires. In the original design of the Shoshone-Denver and the Boulder-Denver lines, two ground wires were incorporated in an effort to avoid lightning troubles. These ground wires were soon abandoned and taken down on account of mechanical difficulties as previously mentioned. All towers on the new tie lines to the Valmont plant are so constructed that a ground wire may be added readily, but to date this has not been done.

The lines from the Shoshone and Boulder hydro plants and the Valmont steam plant converge at a point about four miles west of Denver. From the Dry Creek Substation, 2½ miles west of the terminal, the circuits from the Boulder and Valmont plants are carried on a double-circuit tower line, the construction of which is illustrated in Fig. 16; while the Shoshone circuit is brought the same distance over a single circuit H-frame wood pole line, all on a common right-of-way. This double circuit, 2½ miles long, has been protected with a ground wire through two lightning seasons, with the result that there has been no insulator breakage on account of flashovers, and it is believed that there have been no flashovers during this period on this particular section.

Interruptions

Information which may assist in analyzing the causes of interruptions has been recorded and is summarized

TABLE III
SUMMARY OF INTERRUPTIONS

Line—Year	Spacing	Lightning	Operating error	Plant or sub-station trouble	Secon-dary trouble	Jumper off	Slides	Wind	Rifle shooting	Birds	Unknown	Total line	Total year	Broken con-ductors
1925														
Shoshone-Denver	Flat	49	0	6	1	0	1	8	0	0	4	69		6
Boulder-Denver	Flat	6	0	1	1	0	0	0	0	0	0	8		1
Valmont-Denver	Vert.	6	1	0	0	0	0	0	0	0	1	8		0
Valmont-Boulder	Flat	0	0	0	0	0	0	0	0	0	0	0		0
													85	
1926														
Shoshone-Denver	Flat	46	1	3	4	1	0	1	0	0	7	63		2
Boulder-Denver	Flat	10	0	1	0	0	0	0	0	1	1	13		0
Valmont-Denver	Vert.	14	0	0	0	0	0	0	0	0	0	14		0
Valmont-Boulder	Flat	0	0	1	0	0	0	0	0	0	0	1		0
													91	
1927														
Shoshone-Denver	Flat	35	0	2	5	3	5	5	1	0	4	60		5
Boulder-Denver	Flat	8	0	0	0	1	0	3	0	0	0	12		1
Valmont-Denver	Vert.	11	0	0	0	1	0	0	0	1	2	15		0
Valmont-Boulder	Flat	2	0	0	0	0	0	0	0	0	0	2		1
													89	

in Table III, but the data on outages have not been recorded with a degree of completeness which might be followed were a special study to be conducted on this phase of operation. The quantities of broken conductors, as given in the last column of Table III for each line during each year, are included in their proper places under other headings in the table. In some instances the failure was attributed to wind, while in other instances, the cause was not definitely apparent.

Following the observations which have been made to date on this particular phase of operation, the company has decided that a ground wire properly installed is an

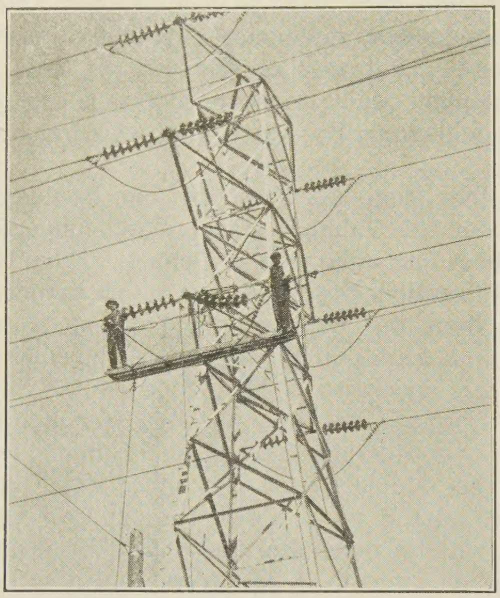

Fig. 16—Type of Double-Circuit Tower

essential adjunct to the system, and is proceeding with its construction, due attention being given to its material, location, method of attachment, and stringing tension.

Insulator Failures

It is of interest to note that in all cases but one of the 50 flashovers which have occurred on new lines, it has been possible to restore service immediately without repair or insulator replacements. In the one case excepted, insulator hardware was burned through on account of a relay failure, and the conductor was dropped.

Conductor Failures

One interesting and peculiar type of conductor break began to develop for the first time in 1921 and has been showing up ever since at an increasing rate. Horizontal spacing is used on the Shoshone-Denver and on the Boulder-Denver lines, these lines having been constructed in 1909. All conductors initially installed consisted of six copper strands with hemp center. Referring to the profile in Fig. 1 of the complete paper, No. 1/0 conductor was strung from Shoshone to Leadville; No. 1 conductor from Leadville to Dillon; No. 1/0 conductor from Dillon to Denver, and No. 1 conductor from Boulder hydro plant to Denver with a tension of 1250 lb. at 60 deg. fahr. Steel towers, with a normal span length of 700 ft., a minimum of 300 ft., and a maximum of 2700 ft. are used the full length of these lines. The general direction of the wind is parallel to the Shoshone-Denver line and at right angles to the Boulder-Denver line.

A close examination of the breaks in the individual strands reveals that some strands fail from crystallization, some from elongation, and some from an apparent crystallization.

Fig. 18 Fig. 19 Fig. 20

Strand Failures

The appearance of a strand failure enlarged to approximately 20 diameters may be seen in Figs. 18 19, and 20. These particular ones are three of a total of four strands in a conductor break having the same characteristic appearance, while the other two strands of the conductor failed as a result of elongation with a slight amount of burning as the conductor finally parted. All six strands parted within a distance of 11 in. along the conductor. It will be noted that a very definite crater exists, partly as a result of the disappearance of metal and partly on account of the necking down of the small amount of metal left around the periphery of the strand. These three illustrations are typical of all those investigated where the fissure had progressed nearly all the way across the strand.

Conclusions

No exceptional difficulties have been encountered in high-altitude operation; where wind velocities are high, jumpers at dead-end towers should be supported.

Insulation problems are no more serious than at sea level.

Arc points appear to be desirable at both ends of insulator strings. Copper and steel conductors, operating above the critical voltage for corona for many years, do not show unusual depreciation.

Horizontal configuration appears to be more desirable than vertical configuration, and properly built ground wires are probably effective.

Satisfactory relaying of high-voltage lines has been accomplished without great difficulty.

Abridgment of

Relation between Transmission Line Insulation and Transformer Insulation

BY W. W. LEWIS[1]
Member, A. I. E. E.

Synopsis.—Principles to be followed in transmission-line construction in order to reduce damage from lightning are recommended in this paper. The major recommendations are as follows: (1) Keep transmission conductors low and arrange horizontally, (2) use ground wires, (3) use sufficient insulation but of a sufficiently low value near stations to protect apparatus, (4) install lightning arresters at the transformers. The arguments leading to these recommendations are outlined in the paper.

DURING the past few years the great majority of overhead transmission systems in this country have grounded the neutral either solidly or through a moderate resistance.[2] Overvoltages due to arcing grounds on such systems are practically absent. Overvoltages due to switching are feared no longer in general on systems with modern insulation and apparatus.

Lightning is the only cause of high voltage which gives serious concern at the present time.[3] In order to combat lightning, transmission engineers have been adding more and more insulation to the lines as well as various special arcing devices, overhead ground wires, etc. A great deal of work has been done in studying lightning and its accompanying phenomena by means of the klydonograph and surge voltage recorder.[4]

Laboratory work has thrown a great deal of light on the effect of impulses on insulation, both of apparatus and transmission lines.[5]

The question now arises as to whether, in the light of present knowledge, we can design a transmission line and its connected apparatus so that they will be reasonably safe against breakdown and interference to service due to lightning. Let us first examine the data upon which such a design shall be based.

1. Central Station Engineering Dept., General Electric Co., Schenectady, N. Y.

2. *Present Day Practises in Grounding Transmission Systems*, Report of Subcommittee on Grounding of Protective Devices Committee, TRANS. A. I. E. E., Vol. 42, 1923, p. 753.

3. *Lightning and Other Experience with 132-Kv. Steel Tower Transmission Lines*, Sindeband and Sporn, TRANS. A. I. E. E., Vol. 45, 1926, p. 770.

1926 Lightning Experience on 132-Kv. Transmission Lines, P. Sporn, 1928. A. I. E. E. Quarterly TRANS. No. 2.

Recent Investigation of Transmission Line Operation, J. G. Hemstreet, TRANS. A. I. E. E., Vol. 46, 1927, p. 835.

4. *Klydonograph Surge Investigations*, Cox, McAuley and Huggins, TRANS. A. I. E. E., Vol. 46, 1927, p. 315.

Measurement of Surge Voltage on Transmission Lines Due to Lightning, Lee and Foust, TRANS. A. I. E. E., Vol. 46, 1927, p. 339.

5. *Lightning and Other Transients on Transmission Lines*, F. W. Peek, TRANS. A. I. E. E., Vol. 43, 1924, p. 1205.

Presented at the Northeastern District No. 1 Meeting of the A. I. E. E., New Haven, Conn., May 9-12, 1928. Complete copies upon request.

Sixty-cycle flashover tests on insulators have been made on strings of various numbers of disks. Most of these tests have been made on standard 10-in. disks spaced 5¾ in. apart. It has been found that the flashover value, when plotted against length of string in inches, gives a straight line on log-log paper. The length of string is the spacing per disk times the number of disks. The curve may also be used for insulators of other spacings not differing greatly in proportions from the 10-in. disk spaced 5¾ in. apart. In this case, it is necessary only to multiply the spacing per disk by the number of disks and enter the curve with the total distance. Table I gives the length of string and 60-cycle flashover for strings of 10-in. disks spaced 5¾ in. apart. The flashover values are plotted against number of disks on Fig. 1.

TABLE I
FLASHOVER OF INSULATOR STRINGS BASED ON 10-IN. DISKS SPACED 5¾ INCHES

No. disks	Length of string inches	60-cycle arc-over kv. eff.	Impulse arc-over kv. max.
3	17.25	200	470
4	23.	255	610
5	28.75	305	750
6	34.5	355	890
7	40.25	400	1020
8	46.	445	1150
9	51.75	490	1280
10	57.5	540	1410
11	63.25	580	1520
12	69.	620	1660
13	74.75	660	1780
14	80.5	700	1900
15	86.25	745	2020
16	92.	785	2140
17	97.75	820	2260
18	103.5	865	2380

The impulse flashover of such insulator strings assumes various values, depending on the nature of the impulse, the steepness of its front, the slope and length of its tail, etc. Numerous tests have been made with the standard wave of the High-Voltage Laboratory at Pittsfield on insulator strings of various lengths, and these tests have been repeated with a great deal of consistency.

The Pittsfield wave is a single impulse with a very steep front, rising to its crest value in approximately one-quarter microsecond or less (depending on the load on the test set), and then decreasing to 50 per cent

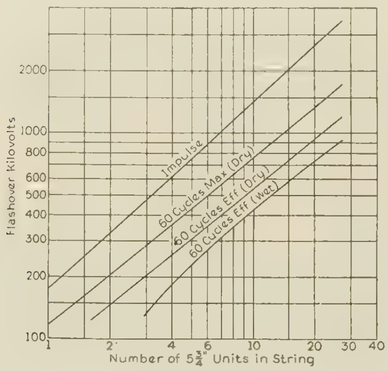

FIG. 1

of the crest value in approximately five microseconds, *i. e.*, the portion of the wave above 50 per cent crest value is approximately one mile in length. This wave is represented in Fig. 2.

The ratio of the impulse flashover to the 60-cycle maximum or crest flashover is called the impulse ratio.[6] It will be seen that this varies from approximately 1.5 to 2 within the range of the curves. A fair average would be 1.8.

If an extremely high potential is applied as compared with the flashover value of the insulators on the tail of the wave, then flashover will take place on the front of the wave. For the particular wave we have been discussing, it has been found that the flashover values thus found are very consistently about 20 per cent

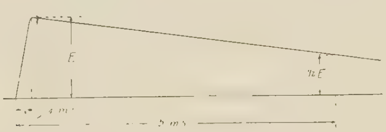

FIG. 2

greater than the values determined when the flashover takes place on the tail of the wave. For other waves, of course, there may be a somewhat different relation between flashover on the front and tail of the wave.

In actual practise, flashover of insulator strings may take place either on the front of the wave or on the tail of the wave, and sometimes even on the crest of the wave. In case flashover takes place on the front of the wave, then only a small portion of the wave passes on to the rest of the line and station apparatus (Fig. 3A). When flashover takes place on the tail of the wave, a longer portion of the wave passes on, and as this represents a greater amount of energy, the wave is capable of doing considerable damage if it reaches station apparatus (Fig. 3B). If the value of the wave is not quite sufficient to flashover the insulator string either on the front or the tail, then the full wave will pass on toward the station (Fig. 3C). In each case there may be considerable attenuation along the line before the wave reaches the station.

During the past few years, numerous data have been accumulated by means of the klydonograph and surge voltage recorder, which has indicated the maxi-

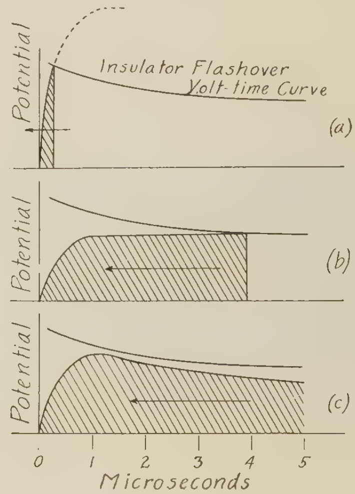

FIG. 3

mum voltage to be expected on transmission lines with present standards of insulation to be in the neighborhood of 10 to 12 times the crest value of the line to neutral voltage of the system.[4]

Table II gives the average number of insulator disks

TABLE II
INSULATION OF ACTUAL LINES

System voltage kv.	Crest value line to neut. voltage kv.	No. of insulator disks: Range	No. of insulator disks: Weighted average	Impulse flashover kv.	Ratio impulse to normal voltage
66	54	4–6	5	750	13.9
88	72	5–7	6	890	12.4
110	90	6–9	7	1020	11.3
132	108	9–12	10	1410	13.1
154	126	10–12	10	1410	11.2
187	153	10–12	10	1410	9.2
220	180	12–16	13	1780	9.9

used on actual systems, also the minimum and maximum number of disks for the various standard system voltages, the data being compiled mainly from the *Electrical World Supplement* of January 3, 1925. The impulse flashover value is given also. From this Table it will be noted that the impulse flashover value is in the neighborhood of 10 to 14 times the crest value of the normal line to neutral voltage. This, together with the results of the klydonograph study, would indicate that the impulse flashover values given in Fig. 1 are fair values to use for the type of impulse which causes flashover on actual systems.

6. *Effect of Transient Voltages on Dielectrics*, F. W. Peek, TRANS. A. I. E. E., Vol. 34, 1915, p. 1857.

According to F. W. Peek's investigations, we may take the maximum potential gradient which may be induced on a transmission line by lightning as approximately 100 kv. per ft. of height of conductor. Actually, there have been measured by surge-voltage recorder, potentials which indicate gradients as high as 40 kv. per ft. of height. The readings obtained are subject to the fact that there is no assurance that the surge voltage recorders were located at the point of highest potential. The potentials are naturally limited by the insulator flashover, and such flashover potentials would require gradients in some cases as high as 60 kv. per ft. of height.

Assuming that the maximum potential gradient of 100 kv. per ft. of height can be obtained, and assuming further that the flashover values given in Fig. 1 are substantially correct, then we have a means of determining whether or not a particular line will be subjected to flashover.

Mr. Peek, in his laboratory investigations, has determined fairly well the effectiveness of overhead ground wires. The protection afforded by the overhead ground wire depends on the distance of the ground wire from the conductors, on the height of the conductors above ground, and on the size of the ground wire and conductors. Generally speaking, however, any one of these factors may be varied within the range of practise without affecting the protective ratio to any great extent. The resistance of the connection to ground also has considerable influence on the protection.

In placing ground wires it is desirable to adhere to the following general rules.

1. The wires should be connected to each tower or connected to ground at each wooden pole.

2. The resistance of the tower footing or the pole ground must be low in order to give the maximum protection.

3. The ground wire should be preferably of the same material as the conductor, or other high conductivity material. This will prevent rusting and will have an appreciable effect in reducing the impedance of the system to line-to-ground short circuits. It will also reduce telephone interference by shunting a good portion of the short-circuit current away from the ground.

4. The ground wires should terminate at the station structure rather than at the first or second tower out on the line. This assures that the last span or two near the station will be protected and that there will be no abrupt change in the surge impedance of the line at the terminal of the ground wire. Such a change in surge impedance tends to cause an upward reflection in the voltage of a wave arriving on the transmission line.

Now, if we know the potential gradients which may be due to lightning, the flashover value of the line insulators, and the protection afforded by overhead ground wires, we are in a good position to determine what must be done to render the transmission line fairly safe from insulator flashover.

In Table VII are given the actual average heights of the lowest conductor at the tower for the various standard system voltages as disclosed mainly from a study of the data given in the *Electrical World Supplement* of January 3, 1925. In this table are given also the potentials which may be obtained with a gradient of 100 kv. per ft. Comparing these potentials with the flashover value of the line insulators in Table II, we see that it is possible to have insulator flashover under the assumed conditions for every system voltage.

TABLE VII
HEIGHT OF ACTUAL LINES AND INSULATION REQUIRED TO PREVENT FLASHOVER

System voltage	Average height of lowest conductor at tower feet	Possible lightning potential 100 kv. per ft.	Potential with two ground wires conductors horizontally arranged	No. of ins. disks required to prevent flashover	Flashover of insulator disks kv.
66	35	3500	1290	9	1280
88	39	3900	1440	10	1410
110	47	4700	1740	13	1780
132	47	4700	1740	13	1780
154	50	5000	1850	14	1900
187	50	5000	1850	14	1900
220	56	5600	2070	16	2140

Assuming the average heights shown in Table VII and a horizontal arrangement of conductors with two overhead ground wires placed above and between the conductors, the potential induced on the conductors will be reduced to approximately 37 per cent of the value without ground wires—*i. e.*, to the values shown in the fourth column of Table VII. Now, in order to prevent flashover it will be necessary to use the number of insulator disks shown in the fifth column of the table. The insulation required to produce immunity in this manner is considerably higher than the present standard.

Mr. Peek has found that grading rings, properly proportioned and properly located, will increase the flashover value of a string of insulators (especially strings containing 10 disks and over) approximately 10 to 15 per cent and advantage may be taken of this effect in reducing the number of insulator disks or in increased factor of safety.

It is apparent from this study that the potential induced on a transmission line is independent of the operating voltage, except in so far as the height of the conductors and the number of insulator disks are affected by the operating voltage. In selecting the number of insulator disks it may not be necessary to consider the extreme potential gradient of 100 kv. per ft. of height. A gradient of 75 kv. per ft. will probably be sufficient to cover the great majority of cases, and a line insulated for this gradient would no doubt be immune from flashover except in rare instances.

Now, what is the situation as regards apparatus insulation, especially transformer insulation? The in-

sulation of power transformers is designed to withstand a certain 60-cycle high-potential test, this high-potential test being, for fully insulated transformers, two times the line-to-line voltage. The test is applied from high-tension winding to low-tension winding and ground. In the so-called reduced insulation transformers, which are built for operation with solidly and permanently grounded neutral, an induced voltage test of 2.73 times the leg voltage is given to the transformer windings.

Naturally, the designers build into the transformer a factor of safety over the Institute test. Such a factor of safety has been worked out by experience and has proved ample to meet the various switching and arcing ground surges to which transformers are subjected.

With the range of line insulation shown in Table II it has been possible for transformers to be subjected to lightning voltages from 10 to 14 times the normal operating voltage with the average line insulation and more than that with the maximum insulation shown in the table. Such voltages are subjected of course to the modification caused by lightning arresters, the capacitance to ground of steel work used in supporting bus structures, etc. Also on any system probably only a fraction of the lightning discharges takes place near stations. However, it is reasonable to suppose that transformers have been subjected many times to ten times normal voltage. Transformers have operated under these conditions with remarkable success, the failures due to all causes, including lightning, being only a fraction of one per cent per year.

It is reasonable to conclude that fully insulated transformers with present standards of insulation will operate successfully on systems with present average insulation. If such line insulation is increased, as now seems to be the tendency, then the transformer insulation must be correspondingly increased, unless the present standard line insulation is retained for a reasonable distance adjacent to the station, say, one-half to one mile.

If fully insulated transformers are on a par or slightly stronger than the present average line insulation, then it is apparent that reduced insulation transformers are too weak, as their strength is only about 80 per cent of that of fully insulated transformers. Reduced insulation transformers for this reason have no place on systems subjected to much lightning, unless the adjacent line insulation is correspondingly reduced.

In order to protect transformers now in operation and future transformers with standard insulation, it is recommended that the line insulation adjacent to stations be not increased beyond the values given in Table IX for at least one-half mile from the station. Beyond that point there is no objection to increasing the line insulation to any value required to give good operation. Such a practise on the part of the operating companies will give the manufacturers a definite standard with which to compare their apparatus design.

If for any reason it is desired to increase the line insulation adjacent to the station, then the apparatus insulation should be increased correspondingly.

In cases where it is thought desirable to increase the line insulation and it is feared that maintaining normal insulation near the station will increase the number of flashovers, this may be compensated for by placing additional ground wires over this portion of the line, thereby reducing the potential induced by adjacent cloud discharges to correspond to the reduced number of insulator disks. Such ground wires should extend to the stations and, in some cases, over the stations, in order to insure that the station apparatus secure the full benefit of the ground wires.

TABLE IX
RECOMMENDED LINE INSULATION

System voltage kv.	Recommended 60-cycle arc-over of line insulators–kv. effective	Corresponding number of 10-in. disks spaced 5¾ inches
66	255	4
88	355	6
110	400	7
132	445	8
154	540	10
187	620	12
220	700	14

In order to provide a further assurance of successful operation and take care of surges of all kinds, it is necessary to by-pass the incoming surge. The cheapest and most effective present form of such a by-pass, is a lightning arrester.

To summarize: We have shown that it is possible to increase the safety of transmission lines and apparatus from lightning disturbances by adhering to the following principles:

a. Construct the transmission line so that the conductors are as near to the ground as the necessary clearances will permit, and preferably build the line with the conductors horizontally arranged.

b. Install one or two overhead ground wires in accordance with the design of the tower and the requirements for reduction in potential imposed by the height of the conductors.

c. Use sufficient insulation on the line to prevent flashover with the maximum potential gradient that may be obtained with the number of ground wires used.

d. Maintain recommended insulation (Table IX) for one-half a mile or so from the station in order to protect station apparatus. Over this section additional ground wires extending to the station may be used in order to place this section on a par with the over-insulated section as far as flashovers are concerned.

e. Install lightning arresters immediately adjacent to the transformers so as to prevent reflection and hold down the potential to a comparatively low value.

Abridgment of

Rationalization of Transmission System Insulation Strength

BY PHILIP SPORN*

Member, A. I. E. E.

Synopsis.—Experience on high-voltage transmission lines has shown numerous failures of apparatus which have indicated a decided lack of coordination of the insulation strengths of the various parts of the transmission system. Apparatus offered by manufacturers for a given service shows wide variations in insulation values. Again the flashover and the breakdown values are not at present sufficiently standardized to be comparable among manufacturers of the same piece of apparatus. The standard tests on different types of apparatus are not properly correlated.

Besides discussing the above situation, this paper points out the causes for the present status and indicates the benefits to be derived by grading the insulation on the entire system. Predetermining the point of electrical breakdown on the system in the case of high voltage surges leads most logically to grading the insulation. This grading should result in fewer major service interruptions, with a localization of trouble on a link of the system where repairs can be made easily and inexpensively.

The paper points out that additional information is required on surge-voltage breakdown of insulation to solve the problem completely but shows that with the present information available a start in grading can be made. The different links in the transmission chain are tabulated according to their relative importance and with this as a starting point, the entire grading scheme is developed to the point of showing relative 60-cycle insulation strength required of the different apparatus used on a transmission system.

It is shown; 1, that at the present time transmission systems in general, are designed without proper consideration from the standpoint of surge voltages which may be imposed upon them; 2, that the grading scheme proposed is possible, although requiring additional operating data and data from the manufacturers to be fully effective; 3, that grading should result in less costly designs and installations; 4, that the net effect will be better performance of the transmission system in service.

* * * * *

I. Introduction

The idea that it ought to be possible to place on a rational basis instead of the present more or less haphazard basis insulation strength of the various portions of a transmission system, is perhaps not new, and undoubtedly has occurred to many. Experience has shown the desirability of working out some such idea. The present paper is to be regarded not as a complete solution but rather an attempt at the beginning of this problem.

II. Present Status in Regard to Transmission Insulation

If one examines different practises, it will be found that one system is particularly bent on over-insulating its lines; another system practises over-insulating of its transformers with its bushings of normal strength, and still another follows the reverse practise of having extra heavy bushings and normal insulation on windings. These conditions will be found to exist in the moderate voltages; sometimes in higher voltages they are even worse.

III. Analysis of the Present Situation

This can be overcome by dividing insulation into classes, each class to contain the whole series of links used in the transmission chain and the entire series properly graded.

V. Fundamentals of the Problem

Before considering a detailed analysis of the various insulation classes, it might be well to consider the causes

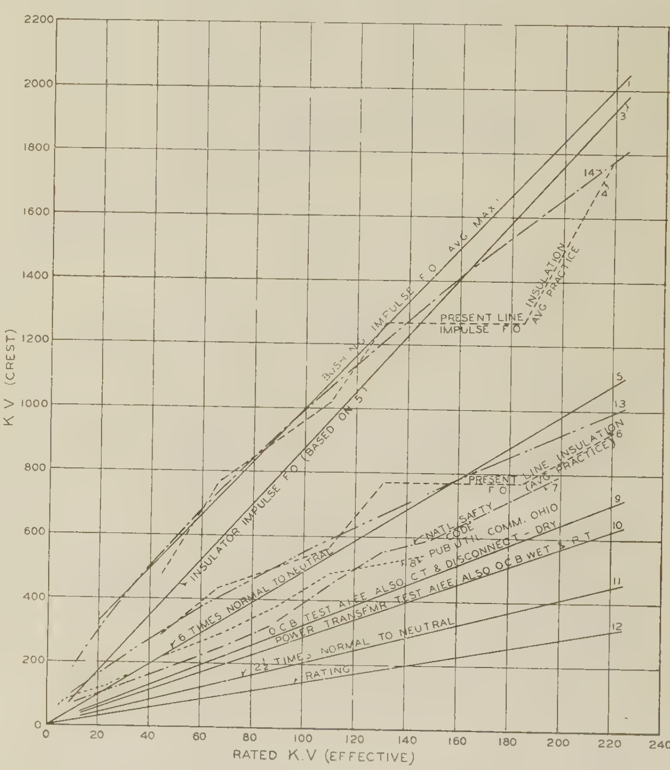

Fig. 1—Transmission System Insulation Strengths Conditions in 1927-1928

1 Bushing impulse voltage F. O. (general average)
3 Line insulator impulse F. O. (based on 6 × normal 60 ~ F. O.)
4 Line insulator impulse F. O. (based on present avg. insulation)
5 6 times normal line to neutral 60 ~ voltage
6 Line insulator 60 ~ F. O. (present avg. insulation)
7 Min. allowable line insulator 60 ~ F. O.—National Safety Code
8 Min. allowable line insulator 60 ~ F. O.—Public Utility Comm. of Ohio
9 60 ~ dielectric test—Oil C. Bs.—C. Ts disconnects—A. I. E. E. dry
10 60 ~ dielectric test power transfs.—P. Ts dry—O. C B. wet—A.I.E.E.
11 2½ times normal line to neutral—60 ~
12 Apparatus rating—60 ~
13 Line insulation (approx. present avg.—60 ~ F. O.)
14 Line insulation (approx. present avg. impulse F. O.)

*American Gas & Electric Co., New York, N. Y.

Presented at the Northeastern District No. 1 Meeting of the A. I. E. E., New Haven, Conn., May 9-12, 1928. Complete copies upon request.

of flashover. Overvoltages may be of several types and of several sources of origin:

1. A straight overvoltage at the power frequency, caused by a system running away, by the crossing of circuits of various potentials, or by some other unusual occurrence.

2. An overvoltage may appear due to arcing grounds. This voltage may have a frequency of the order of thousands of cycles. Except, of course, for the isolated neutral systems which today are rare, it will not appear.

3. Overvoltages may take the form of impulse voltages and these in turn may be caused by either switching or lightning.

Let us consider a power system transmission chain, list all the apparatus and equipment, and see whether a definite system of grading cannot be worked out for the various insulation members.

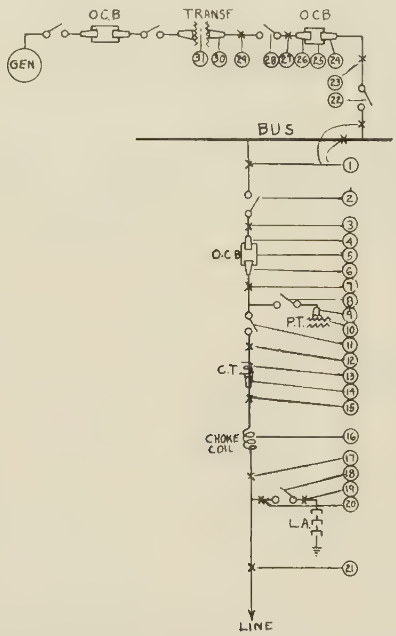

Fig. 2—Typical High-Voltage Station

1 Bus and bus tap insulators
2 Disconnect on bus
3 Insulator—line side bus disconnect
4 O. C. B. bushing—bus side
5 Oil circuit breaker
6 O. C. B. bushing—line side
7 Insulator—line side O. C. B.
8 Disconnect—on P. T.—line side O. C. B.
9 Bushing on P. T.
10 Potential transformer
11 Disconnect—line side O. C. B.
12 Insulator—line side O. C. B. disconnect
13 Current transformer
14 Bushing on C. T.
15 Insulator—lineside C. T.
16 Choke coil
17 Insulator—lineside choke coil
18 Disconnect on L. A.
19 Insulator on sphere-gap
20 Insulator on L. A. tap
21 Line insulator
22 Disconnect on bus
23 Insulator—O. C. B. side disconnect
24 O. C. B. bushing—bus side
25 Oil circuit breaker
26 O. C. B. bushing—transformer side
27 Insulator—transformer side O. C. B.
28 Disconnect — transformer side O. C. B.
29 Insulator—transformer side disconnect
30 Power transformer H. T. bushing
31 Power transformer H. T. winding

Fig. 2 is representative of a typical high-voltage generating station with a generator and transmission line connected to the bus. It will be seen in Fig. 2, that some of the parts have been rather finely subdivided as in the first analysis, it was thought best to go the limit in the subdivision of parts, and later consolidate such members as could be placed in the same class.

VI. Proposed System of Grading

In Table V there has been set up a proposed system of grading for every member shown in Fig. 2. In the setting down of orders of importance certain assumptions have been made. These are as follows:

TABLE V

RATED RELATIVE IMPORTANCE OF APPARATUS ON LIGHTNING VOLTAGE CONSIDERED FROM POINT OF VIEW OF

A. Minimum number of interruptions
B. Minimum danger of complete interruption
C. Minimum cost of repairing damaged apparatus

PROPOSED GRADING—STRONGEST INSULATION (1) TO WEAKEST (31)

Columns 1	H. T. Generating station			H. T. Switching station			Step down & switching station		
Order of insution strength	2 A	3 B	4 C	5 A	6 B	7 C	8 A	9 B	10 C
1	21	1	31	21	1	5	21	1	31
2	20	2	25	20	2	10	20	2	25
3	18	22	5	18	3	13	18	22	5
4	19	3	10	19	4	4	19	3	10
5	17	23	13	17	5	6	17	23	13
6	16	4	30	16	6	9	16	4	30
7	15	24	24	15	10	14	15	24	24
8	14	5	26	14	13	1	14	5	26
9	13	25	4	13	9	2	13	25	4
10	12	31	6	12	14	11	12	31	6
11	11	30	9	11	7	8	11	30	9
12	8	26	14	8	8	3	8	26	14
13	9	28	1	9	11	7	9	28	1
14	10	29	22	10	12	12	10	29	22
15	7	27	28	7	15	15	7	27	28
16	6	6	2	6	16	16	6	6	2
17	5	13	11	5	17	17	5	13	11
18	4	14	8	4	20	20	4	14	8
19	3	10	23	3	18	18	3	10	23
20	2	9	27	2	19	19	2	9	27
21	1	8	29	1	21	21	1	8	29
22	22	7	3				22	7	3
23	23	11	7				23	11	7
24	24	12	12				24	12	12
25	25	15	15				25	15	15
26	26	16	16				26	16	16
27	27	17	17				27	17	17
28	28	20	20				28	20	20
29	29	18	18				29	18	18
30	30	19	19				30	19	19
31	31	21	21				31	21	21

1. That the station has two busses.

2. That there be a transfer or inspection oil switch available at the station.

3. That in case of a lightning impulse or discharge sufficiently high to spill over coming into the station, the spilling over at one point will prevent the impulse with a dangerously high head going any further.

TABLE VI

GRADING INSULATION FOR LIGHTNING IMPULSE SURGES

1 = Highest insulation down to 15 = Lowest Insulation for Results Indicated

Column Member	Apparatus	1 Min. no. of interruptions	2 Min. danger of complete interruptions	3 Min. cost of apparatus repair	4 Ave. position from columns 1—2—3	5 Suggested for general conditions
A	Oil switch (internal make-up)	13	4	2	6–1/3	1
B	Insulators—Bus side of oil switches	10	1	9	6–2/3	2
C	Power transformer windings	15	5	1	7	3
D	Oil switch bushings	12	3	6	7	4
E	Potential transformer windings	9	9	3	7	5
F	Disconnects—Line side of oil switches	3	7	11	7	6
G	Insulators—Line side of oil switches	2	8	12	7–1/3	7
H	Current transformer windings	7	11	4	7–1/3	8
I	Disconnects—Bus side of oil switches	11	2	10	7–2/3	9
J	Power transformer bushings	14	6	5	8–1/3	10
K	Potential transformer bushings	8	10	7	8–1/3	11
L	Current transformer bushings	6	12	8	8–2/3	12
M	Insulators on line	1	15	15	10–1/3	13
N	Choke coils	5	13	13	10–1/3	14
O	L. A. sphere-gap insulators	4	14	14	10–2/3	15

4. The effect of a change in the entrance arrangement of ground wires, the effect of the protective values of the bus structure itself, and the effect of the lightning arrester, have been entirely neglected.

Obviously as it stands, Table V does not offer a practical setup. There are altogether too many members. In Table VI, the total number of 31 members has been reduced to 15.

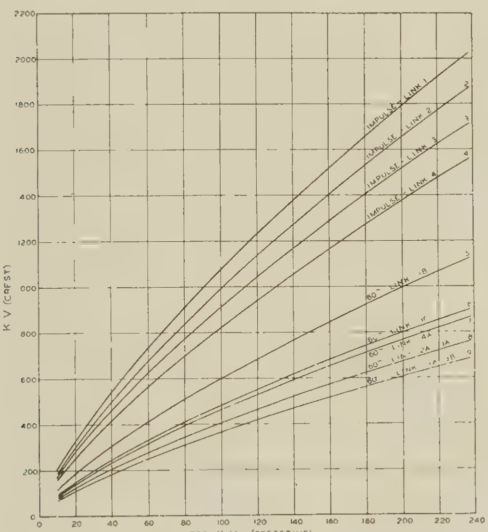

FIG. 4—PROPOSED GRADING OF TRANSMISSION SYSTEM INSULATION STRENGTHS

Showing impulse and 60-cycle flashover or breakdown voltages. For references to links, see Table VII

Table VII proposes that the insulation on a transmission system should be divided into four groups and that the insulation of these groups follow a definite order. Table VII further suggests that the insulation of a group of members in the transmission system consisting of oil switch bushings, potential transformers, disconnect switches, current transformers, etc., be all held at the same level. These four groups are subsequently referred to as the four links.

In Figs. 5 and 5A the curves of 60-cycle strength developed in Fig. 4, have been plotted in terms of r. m. s. values on both coordinates.

In analyzing these curves it will be seen that while it is possible to rationalize and work out a system of insulation strength with comparatively few links in a particular chain, the problem is not quite so simple when the 60-cycle strength is considered.

TABLE VII

PROPOSED INSULATION CHAIN

Rationalized order of insulation Col. 5-Table VI	Apparatus	Suggested order of links in chain
1	Oil switch internal make up	1
2	Insulators—Bus side of oil switch	
3	Power transformer windings	2
4	Oil switch bushings	3
5	Potential transformer windings	
6	Disconnects—Line side of O. S.	
7	Insulators—Line side of O. S.	
8	Current transformer windings	
9	Disconnects—Bus side of O. S.	
10	Power transformer bushings	
11	Potential transformer bushings	
12	Current transformer bushings	
14	Choke coils	
15	L. A. sphere gap insulators	
13	Insulators on line	4

SUBDIVISION OF LINKS

1 A—Oil switch (exclusive of bushings)
1 B—Bus insulators—(suspension or strain)
1 C—Bus insulators—(Post type)
2 A—Power transformers (exclusive of bushings)
3 A—Bushings and disconnects
3 B—Transformers (C. T. & P. T.)
4 A—Short section of line nearest S. S. (About 1 mile).

Leaving the 60-cycle tests as they are, however, it should still be possible to work up a rationalized system of insulation strength under impulse conditions and, if the system is a proper one, it should be unnecessary to disturb it in any way when finally the 60-cycle end is rationalized.

Keeping this in mind, the writer suggests the system shown by curves 1 to 4, Fig. 4, as fulfilling the necessary requirements. So long as apparatus and insulation strength are specified and bought on the basis of normal or line voltage, difficulty will be encountered in utilizing on a system of a definite voltage, apparatus that might have a nominal rating of a considerably higher voltage. This difficulty could be avoided definitely if apparatus were bought on the basis of normal operating voltage and with insulation strength of a certain definite chain. If once the idea is embraced that insulation strength does not always go together with operating voltage, and it is specified independently then it will be possible to realize the idea of obtaining for each system, the

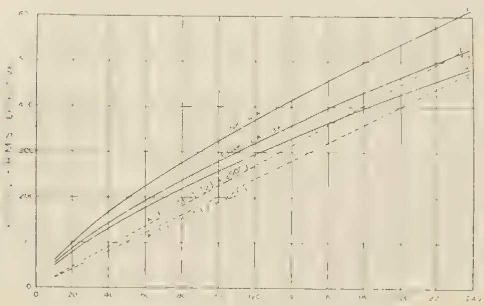

Fig. 5—60-Cycle Effective Voltage Breakdown of Links and A. I. E. E. Test Specifications

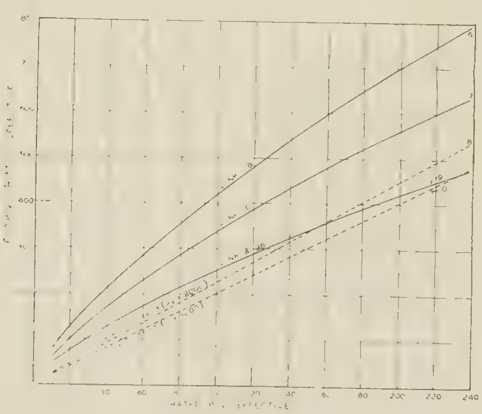

Fig. 5a—60-Cycle Effective Voltage Breakdown of Links and A. I. E. E. Specifications

insulation strength really necessary. In Table VIII nominal kilovolt classes have been purposely indicated, but there is really no valid reason why these should be adhered to, or why these should appear in any specifications or design calculations.

TABLE VIII
IMPULSE VOLTAGE FAILURE FOR PROPOSED INSULATION CHAINS

Insulation chain no.	1	2	3	4	5	6	7	8	9	10
Nominal kv. class	25	37½	50	70	90	115	145	175	205	237½
Link no.	All values below in crest kv.									
1	382	526	639	819	985	1185	1405	1620	1830	2020
2	353	486	592	756	910	1095	1296	1495	1686	1870
3	324	445	542	693	834	1005	1190	1370	1548	1715
4	294	405	492	630	757	912	1080	1245	1405	1555

IX. Summation

The writer believes he has shown that:

1. The present status with regard to insulation practise and standards is not satisfactory. This is as true with regard to the manufacture and application of apparatus as it is with regard to the various rules and regulations issued by state and other regulatory bodies.

2. There is no single cause for the present situation, but there are many contributory factors, some of which were perhaps unavoidable.

3. The net effect of the present status is one of confusion in regard to the specification and the purchase of insulation value. Furthermore, the problem of designing a system that is properly correlated in insulation strength is extremely difficult. In the long run this results, in more trouble on the transmission system than is necessary or desirable.

4. It would be highly desirable to bring about a condition for eliminating some of these difficulties without making a separate research of each problem of transmission. If a system of grading were worked out and adhered to by all manufacturers and users of apparatus and equipment, many of the difficulties today encountered in the problem of making a transmission system give continuous service would be done away with.

5. Before such a state can be reached more exact data with regard to the characteristics of switching surges and lightning waves, and a definite agreement as to how these various quantities are to be measured, will be necessary. In other words, to have standards for each.

6. Assuming that all the data outlined in paragraph 5 are obtained, a method of arriving at the order of grading insulation can be formulated. By the proper consolidation of various members it is possible to reduce the transmission chain links that will be graded from each other to a reasonable number. A four-link system was proposed; but while four links are adequate from a lightning standpoint, from the power-frequency standpoint the problem is considerably more complicated due to the different impulse ratios. This problem will require further study.

7. Without changing for the present the specifications covering power-frequency strength, a series of insulation chains that will be properly graded from the standpoint of lightning strength can be worked out. A definite series of that type was proposed. By elimination of nominal operating voltages, the probability of obtaining proper insulation strength will in many cases be enhanced.

8. If the systems proposed are adopted, the ultimate result ought to be less expensive and the design more satisfactory; in other words, giving better continuity on the transmission system as a whole.

Abridgment of

Utilization of Lodgepole Pine Timber for Poles

BY R. W. LINDSAY[1]

Associate, A. I. E. E.

Synopsis.—With an ever-increasing demand for poles used in the construction of power and communication lines new sources of supply must be developed from time to time. Along the Rocky Mountain Range are found large stands of various species of timber suitable for the production of poles and so far not utilized to any appreciable extent. This paper outlines briefly the selection of lodgepole pine timber for this purpose, relates the past experience with such poles used in certain test lines, and describes in general the production and preservative treatment of the poles.

* * * * *

Introduction

During recent years the demand for poles to be used in constructing telephone, telegraph, signal, light and power lines has increased rapidly. In the eastern part of the United States the cedar stands of Maine have been largely depleted of timber of sufficient size to produce long and large-sized poles, and the northern white cedar stands of the Great Lakes region are facing the same situation. Although the blight of the chestnut timber in the Appalachian region has somewhat stimulated the current production of chestnut poles, a large curtailment of the future supply of these poles is inevitable. In all pole-producing areas, including the enormous stands of red cedar timber throughout the western coast regions and in the southern pine stands of the South, the hauls are becoming longer, and the charges for stumpage are likely to increase from time to time.

In the face of these conditions, and looking into the future, it has been felt that sooner or later it would be necessary to develop a satisfactory substitute for wooden poles or that new sources of supply must be found. To date, substitutes for wooden poles have not been found to be altogether satisfactory or economical, and it is therefore logical for companies serving the public in sparsely settled territory, necessitating heavy expenditures for pole plant, to look for new sources of pole supply, not only for present consumption but to protect their growing demands of the future.

It has been known for a long time that the Rocky Mountain Range, from New Mexico in the South to Montana in the North, is covered with timber of the proper size to make poles, the principal species available being lodgepole pine, Engelmann spruce, western yellow pine, and Douglas fir. There are various reasons why this timber thus far has not produced many poles; but the chief reason is probably the fact that when these species, with the exception of Douglas fir, are placed in the ground they do not resist the attack of fungi to any great extent. It has been recognized, therefore, that unless a satisfactory treatment could be developed to protect the wood from the infection of fungi, the vast amount of pole timber close at hand could not be economically utilized.

In 1923 an investigation was undertaken by The Mountain States Telephone and Telegraph Company to determine (1) whether or not satisfactory poles could be obtained from the native timber, and (2) whether or not a reliable preservative method could be developed to protect the poles after being placed in the ground. In order to decide whether or not satisfactory poles could be obtained from the native timber, three major questions had to be definitely determined:

a. Whether or not suitable pole-making timber could be found in large quantities in accessible places and close to the railroad.

b. Whether or not, from the standpoints of strength, shape, grain, etc., the timber would be satisfactory.

c. Whether or not poles from this timber could be produced at prices equal to or lower than current prices of other poles.

Available Pole Timber

Recent surveys made by the United States Forest Service show that on certain test sections in several of the national forests of Colorado and Wyoming from 53 to 176 poles per acre can be produced.

From sections that have been cut for the purpose of securing ties, sawlogs, props, and poles, and in other sections where special surveys have been made, it has been possible to gain a general idea of the proportion of available poles to the total number of sawlogs and ties that this timber affords. The amount of sawlog and tie timber available in the Colorado and Wyoming National Forests (Wyoming and Teton National Forests in Wyoming not included) is as follows:

Species	No. of Ft—Board Measure
Lodgepole pine	10,599,078,000
Engelmann spruce	15,236,420,000
Western yellow pine	2,031,688,000
Douglas fir	1,959,289,000

From the above information, and allowing fully for trees that would not make satisfactory poles, it can

1. Gen. Eng. Dept., The Mountain States Telephone and Telegraph Co., Denver, Colo.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-28, 1928. Complete copies upon request.

be conservatively estimated that there are now in the Colorado and Wyoming National Forests 200,000,000 trees that would make specification poles. These poles range from 20 ft. to 85 ft. in length, with the majority under 50 ft. in length. Besides this growth there is an enormous amount of privately owned pole-sized timber here and there along the range. The states of Montana and Idaho also have very large stands of available pole timber on United States national forests. In Colorado, Wyoming, Montana, and Idaho this timber, consisting mostly of lodgepole pine and Engelmann spruce, can be secured in large quantities within from two to ten miles of existing railroad shipping points which are connected with transcontinental railroads, thus making possible comparatively short hauls.

The timber controlled by the United States Forest Service will always be productive of poles in very large quantities. The cutting is so programmed that the mature timber is cut first, the less mature next, and so on until the crop is either materially thinned or entirely cut. The age of the present mature stands varies from 75 to 300 years. Lodgepole pine reseeds itself, and after being cut a new growth appears in a short time. Reproduction or second growth in pole sizes can be obtained within from 75 to 100 years, depending upon the soil characteristics, growing conditions, etc.

Timber Characteristics and Tests

In selecting pole material the fiber strength in bending is a very important consideration. The strength of pole timber is usually determined by testing the poles in a device by means of which the load, distances from the load to the supports, and the deflections can be accurately measured; and practically all tests of lodgepole pine timber have been made in a standard laboratory testing machine.

Comparative tests[2] of lodgepole pine, Engelmann spruce, and cedar poles were made in 1911 at the University of Colorado, at Boulder, Colorado, by Notman Betts and A. L. Heim, engineers in forest products. Twenty western red cedar poles which were cut near Edgemore, Idaho, and purchased on the Denver market, 22 lodgepole pine poles cut in the Deerlodge National Forest, Montana, besides 20 lodgepole pine poles, and 20 Engelmann spruce poles, fire-killed ten years and cut in Colorado, were all shipped to the University of Colorado for these tests. The strength in bending was determined by placing the poles in a Riehle testing machine and applying a load until failure occurred, and the fiber strength at elastic limit, modulus of rupture, stiffness factor, and modulus of elastic resilience were determined for all poles considered. In addition, the moisture content, annular rings per inch, proportion of heartwood and sapwood, and the weight per cubic foot were determined. The general results of these tests were as follows:

2. This report is covered in detail by Bulletin No. 67, U. S. Dept. of Agriculture, dated March 17, 1914.

1. Air-seasoned lodgepole line is superior to western red cedar in all the mechanical properties determined.
2. Fire-killed lodgepole pine is only 80 per cent as strong as western red cedar at maximum load.
3. Fire-killed Engelmann spruce poles are inferior to cedar and pine in all mechanical properties.

The comparative average strength of the cedar, air-seasoned and fire-killed lodgepole pine, and the fire-killed Engelmann spruce is shown clearly in the following table:

	Moisture content	Lb. per sq. in. modulus of rupture	Lb. per sq. in. fiber stress at elastic limit
Western red cedar	15.1	6,885	4,430
Lodgepole pine (air-seasoned)	21.9	7,680	5,280
Lodgepole pine (fire-killed)	16.9	5,481	4,327
Engelmann spruce (fire-killed)	16.3	4,378	3,489

In 1926 the Mountain States Telephone and Telegraph Company made similar tests of 53 lodgepole pine poles. All the poles were cut green in the Sargent, Pitkin, and La Veta Pass districts of Colorado. Thirty-one of the poles tested were open tank-treated with creosote, the temperature of the hot bath during the creosote treatment having ranged between 200 and 260 deg. fahr. These poles were shipped to the University of Colorado, at Boulder, and there tested in the same Riehle machine that was used by Betts and Heim in 1911. To determine the modulus of rupture the poles were placed in the machine in 20-ft. lengths in order to allow both ends of the pole to rest on the bed of the machine. The load was applied at a uniform speed of approximately one inch per minute. The deflection of the pole was noted at intervals of 1000 lb., until a total load of 6000 lb. was reached, after which the machine was kept in balance, the deflection being noted at 250-lb. intervals until failure occurred. The characteristics of each fracture were carefully examined, and data were tabulated regarding the relative location of large knots, the type of fracture, and whether or not the pole failed in tension or compression. In the tests the annular rings per inch, twist in grain per 20 ft., taper, moisture content, and specific gravity were also determined.

The main conclusions drawn from these tests were as follows:

1. The open-tank treatment of the poles did not show a positive tendency either for increasing or decreasing the strength of the pole.
2. A slight tendency toward an increase of strength with a decrease in moisture content was noted.
3. Large knots or rings of knots were found very objectionable from the standpoint of strength.
4. The modulus of rupture for the 53 pieces averaged 7723 lb. per sq. in. The average moisture content was 15.98 per cent.

In 1927 the Bell Telephone Laboratories made tests of pressure-treated creosoted lodgepole pine poles at the

University of Colorado. The average modulus of rupture determined in these tests was 6214 lb. per sq. in.

When considered as to shape, grain, and other physical characteristics necessary for satisfactory pole material, all species—that is, Engelmann spruce, lodgepole pine, Douglas fir, and western yellow pine—would qualify and would rank in the order named in so far as desirability is concerned. This rating is determined by an examination of the timber after it is cut into poles, noting the taper, the size of knots, the twist in grain, the thickness of sapwood, the extent of undesirable scars, and other features inherent in its growth. Western yellow pine grows generally in rather open areas, is found in large trees, and has large knots; moreover, extensive pole-producing areas are scarce.

Production Costs

At the time this investigation was made, all cost figures as to stumpage, cutting, skidding, hauling, and loading poles on the cars indicated that poles in most of the available Rocky Mountain areas could be produced at equal or less cost than those shipped in from other sources of pole supply, with the possible exception of southern yellow pine in some districts.

In connection with the cost of producing poles in this territory the freight factor is very important. For example, poles can be delivered in Colorado from the pole-producing areas of either Colorado or Wyoming at a freight rate less than one-half the rate from other sources.

Lodgepole Pine and Experimental Lines

The lodgepole pine, because of its existence in such large quantities and in such favorable locations, from a cutting and shipping standpoint, and also due to its greater fiber strength than that of the Engelmann spruce, was chosen as a logical pole timber with which to experiment.

It was recognized that the successful and profitable utilization of lodgepole pine timber for poles could not be expected unless a satisfactory treatment could be employed that would be effective in protecting the wood from rotting after the poles were placed in the ground; and it is now an established fact that this timber can be so protected, as shown by experience with the following lines.

In 1909 at Norrie, Colorado, 1022 fire-killed lodgepole pine poles were butt-treated with creosote oil. The treatment consisted in placing them in a vat containing the oil, which was heated for a sufficient time, allowed to cool, and then drawn off. In this process a penetration of from one-eighth inch to one-fourth inch was obtained, which under present-day methods is considered shallow penetration. One very important factor which favored these poles was that they were fire-killed and thus perfectly seasoned, and therefore checked very little after they were placed in the lines. Of these poles, 561 were placed in service in Rifle, Colorado, by the Rifle Heat and Power Company, and a line was also built extending from Rifle to their power plant, a distance of approximately twelve miles. These poles were inspected in 1917, 1920, and again in 1926. After 17 years' service, 88.4 per cent of the poles were found to be sound, 2.6 per cent contained decay, and 9 per cent had been removed. All tops were inspected and only one pole showed signs of decay above the ground.

In 1910 The Mountain States Telephone and Telegraph Company placed in service 759 poles which were fire-killed and treated at Norrie in the same manner as the poles placed at Rifle. They were used in a line between Hotchkiss and Crawford, Colorado, and to this date, after eighteen years' service, no resplacements have been made, although 42 poles have been reset and 10 have been reinforced.

Studies of pole-line inspection reports show that very few poles in the Rocky Mountain territory become infected and rot above the ground line. This is probably due to the lack of moisture necessary to fungi growth. For this reason it is felt that in this territory it is neither necessary nor economical to treat poles above the ground line.

In the light of this past experience it is reasonably certain that, when seasoned and properly butt-treated with dead oil of coal tar, lodgepole pine poles will prove both satisfactory and economical for the construction of power and communication lines throughout large areas of the West.

Production

Tentative specifications for lodgepole pine poles were drafted in 1924. In general, these specifications followed those for southern yellow pine poles, taking into consideration, however, the characteristics of the lodgepole pine timber. In November, 1926, specifications for lodgepole pine poles and the creosote treatment thereof were drafted by engineers of the American Telephone and Telegraph Company. These specifications were based upon the experience gained in handling, inspecting, and treating these poles and the tests made to determine their strength in bending. These specifications are still in force.

In 1924 arrangements were made with a timber company to cut approximately 10,000 lodgepole pine poles in the vicinity of Sargents and Pitkin, Colorado. Due to the fact that any oil treatment is of little value in this territory unless the poles are properly seasoned, an effort was made to cut these poles so that they would season during the months of June, July, and August previous to their shipment to the treating plant the following January and February. In the seasoning process the moisture content reduces from 60 to 90 per cent to 20 to 25 per cent. The seasoning is valuable for three reasons:

1. It reduces the weight of the pole, thereby effecting savings in freight and hauling charges.
2. The shrinkage in the wood fiber produces checks which can be stapled and controlled before the pole is treated and placed in service.

3. Poles having a heavy twist tend to straighten out when seasoning. If poles are placed in the line when green, the gains become out of line as the poles season, which, in some cases, necessitates regaining and retying the wires in order to relieve the tension on one side of the arm.

In an endeavor to control the checking of the poles after they have been treated, anti-splitting staples are used for controlling large season checks. These staples are driven into the poles, spanning the checks to prevent further opening. This practise is also employed to control checks in western cedar poles. During the seasoning process small poles shrink from ¾ in. to 1 in. in circumference, while large poles shrink from 1½ in. to 2½ in. in circumference, depending upon the size of the pole, the age of the tree, and other factors. It is therefore absolutely necessary that poles be cut from six to nine months in advance of using them, in order that they may be properly seasoned. It is also more economical for the producer to cut poles when the sap is up and the bark can be removed easily, which period is generally between April 15 and August 1. All cutting operations, of course, cannot be done during this time, but it is a great aid to the cutter if he can cut and peel a large number of his poles at this opportune time.

In most cutting areas it is more economical to haul the poles from the woods to the railroad on snow with sleds than any other way, although in a few localities where road conditions permit probably a wagon or tractor could be operated satisfactorily, but in general such a method is expensive. After being cut, limbed, and peeled, the poles must be skidded to the roads, sorted fairly well according to size and class, and placed on timbers to minimize the chance of becoming infected with fungi growth and to aid in their further seasoning. After snow falls in large enough quantities to permit sledding, the poles are hauled to the railroad and there placed on skids, assorted by classes and lengths to await inspection.

It can readily be seen that it is necessary carefully to program the pole requirements far enough in advance to allow the producer to cut and haul the poles at the most economical time and still have the proper time for seasoning.

Returning to the activities of The Mountain States Telephone and Telegraph Company directed toward determining the feasibility of lodgepole pine pole production, and referring to the arrangements made in 1924 for the cutting at Sargents, Colorado, after these poles were fairly well seasoned in the woods or at landing yards along the railroad, they were shipped to Salida, Colorado, for treatment.

Preservative Treatment

In the meantime an open-tank creosoting plant was constructed at Salida, Colorado, for the purpose of treating poles. Salida was selected as the logical location for this plant because it is near the center of the pole-producing timber on the Denver and Rio Grande Western Railroad, and a junction point of the narrow and standard-gage routes of this system. The vats of this plant were constructed in general according to plans furnished by the American Telephone and Telegraph Company. There are two treating vats 9 ft. wide, 24 ft. long, and 10 ft. deep. In the bottom of each vat is a steam coil protected by a steel grid. There are two storage tanks for the dead oil of coal tar, one called the cold tank and the other called the hot tank, each containing a heating unit to maintain the oil at the proper temperature. The heating unit in the cold tank maintains the temperature of the oil at approximately 100 deg. fahr. in winter weather and by circulating cold water through this unit during the summer time, the cold oil can be kept at a temperature of approximately 100 deg. fahr. The vats and tanks are supplied with steam from a 40-hp. boiler and under a pressure of 45 lb. per sq. in. A pit is located between the treating vats, in which is mounted a centrifugal pump driven by an electric motor; and the vats, pump, and tanks are connected with eight-inch pipe lines. This arrangement provides for pumping the oil rapidly out of the vat after the hot treatment and pumping cold oil back into the vat to continue with the cold treatment.

Experiments supervised by the Department of Development and Research of the American Telephone and Telegraph Company were carried out to determine the proper preparation of the poles and the character of the treatment which would produce the best results. In order to insure even and deep penetration it was found necessary to remove all pink bark on winter-cut poles and also the transparent skin on summer-peeled poles. The necessary shaving of the poles was done with an ordinary draw knife. It was also found that the most desirable results could be obtained by treating the poles in a hot oil bath for seven hours at a temperature of from 225 to 250 deg. fahr., after which the hot oil was replaced quickly with cold oil and the treatment continued for an additional seven hours at a temperature of from 100 to 110 deg. fahr. With this treatment a penetration of oil was secured ranging from ⅝ in. to 2½ in., with an absorption averaging 2.2 gal. per pole. It was found that by raising the temperature of the hot bath from 225 to 250 deg. fahr. the absorption of oil greatly increased.

Test pieces of Douglas fir were treated, and it was found that very little penetration could be secured. Lodgepole pine generally has a thick sapwood, while that of Douglas fir is relatively thin, In either species under ideal conditions the sapwood can be penetrated, but very little, if any, penetration can be secured into the heartwood. Tests of fire-killed lodgepole pine timber were made, and it was found that a penetration of more than one-half inch was impossible, regardless of

the temperature of the hot bath. In this connection it was impossible to locate stands of suitable fire-killed lodgepole pine in Colorado.

During 1925 approximately 3500 poles were shipped to Salida, where they were prepared for treatment, treated, and reshipped to their destination. The following year 21,000 poles were cut in the vicinity of Sargents, Pitkin, and La Veta Pass, Colorado, treated at Salida, and placed in lines in Colorado, Wyoming, and Utah. In 1927, 16,000 poles were produced in the same locality. In 1927 arrangements were made to expand the production, and contracts were made with a producer on the Moffat Railroad near Phippsburg, Colorado, and one on a branch railroad near Laramie, Wyoming, with the result that the total production in 1928 will be in the neighborhood of 35,000 poles. As the production and consumption of these poles increases, producers should be secured in Montana and Idaho.

Conclusion

There is every reason to believe that tank-treated lodgepole pine poles will have an average life in service of at least fifteen or twenty years, and possibly longer. There are many factors that affect the ultimate wire load of a telephone pole line, and often this load increases faster than was originally anticipated, with the result that the pole is found to be undersized long before it has been condemned; also, at times other unforeseen factors necessitate moving the pole before its life has been spent. In this territory it now appears that a pole with the lowest possible first cost and a fairly long life is more economical than a pole with a higher first cost and longer life. In other parts of the United States where the density of poles is greater and poles can readily be recovered and reset without damaging the treated portion, different conclusions may be reached.

From the foregoing outline of the investigations thus far made to determine the field of usefulness offered by lodgepole pine timber as a source of pole supply, there can be found justification for continuing and expanding this production, with full confidence that through the employment of proper methods of cutting, seasoning, and treating, lodgepole pine poles will prove highly satisfactory for the construction of the ever-increasing number of power and communication lines traversing the western plains and Rocky Mountain region.

Abridgment of

Electrical Features of the Conowingo Generating Station and the Receiving Stations in Philadelphia

BY R. A. HENTZ[1]
Member, A. I. E. E.

Synopsis.—The paper outlines the principal electrical features of the Conowingo development. This includes a description of the main units and their connections, an outline of the station auxiliary supply, and the 220,000-volt substation which it was necessary to build on the roof of the power plant.

A description is included of the 220,000-volt substation at Plymouth Meeting, the Philadelphia terminus of the Conowingo lines, as well as the lines of the Pennsylvania-New Jersey Interconnection. At this substation are located the 30,000-kv-a. synchronous condensers installed for stability purposes, as well as a 66-kv. installation. Three-winding, 220/69/13.3-kv. self-cooled transformer banks of 100,000-kv-a. rating, arranged for tap changing under load, are installed here.

A description is also included of the Westmoreland Substation where the 66-kv. lines from Plymouth Meeting tie in with the 66-kv. "backbone" of The Philadelphia Electric System. 30,000-kv-a. synchronous condensers for power-factor correction are located at this substation, as is also an extensive 13,200-volt installation for controlling transmission lines to various distribution substations.

* * * * *

THREE stations or substations are involved in delivering the electrical energy from the Conowingo development into Philadelphia:

a. The Conowingo Hydroelectric Generating Station.

b. The 220/66-kv. step-down substation at Plymouth Meeting.

c. The combined 66-kv. switching station and 66/13.2-kv. substation (known as Westmoreland Substation) in Philadelphia where tie-in with the existing system of The Philadelphia Electric Company is effected.

These, together with the steam generating stations and high-tension substations of the Philadelphia Electric system, are shown in Fig. 1.

Conowingo Generating Station

The ultimate development provides for eleven 40,000-kv-a. generators and three 220-kv. transmission lines, of which seven generators and two lines are being installed initially.

13.8-Kv. and 220-Kv. Layout. Fig. 2 is the main one-

1. Engineer, Station Electrical Div., Philadelphia Electric Co., Philadelphia, Pa.

Presented at the Baltimore Regional Meeting of the A. I. E. E., Dist. No. 2, Baltimore, Md., April 17-20, 1928. Complete copies upon request.

line diagram,—the initial installation shown solid, the future, dotted.

The 40,000-kv-a. main units generate energy at 13,800 volts and step up to 220,000 volts through 80,000-kv-a. transformers. It is planned to operate the plant as a whole in parallel on the 220-kv. bus, but to reduce the cost, two generators are tied together to a

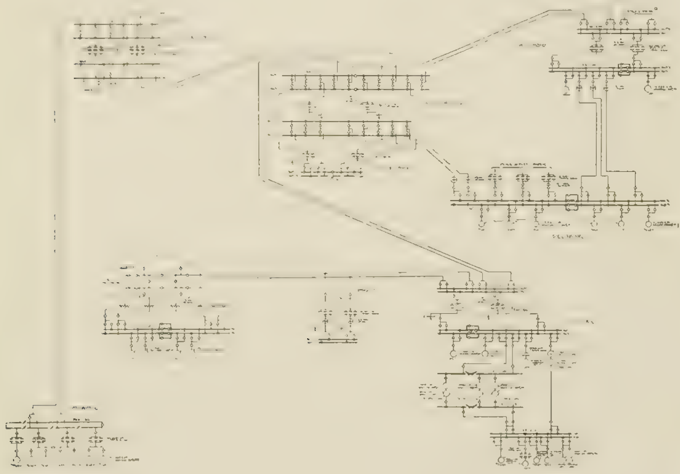

FIG. 1—MAJOR CONNECTIONS OF THE PHILADELPHIA ELECTRIC CO. SYSTEM

No. 3, No. 4, No. 5, and No. 6 sections are tied together by an oil circuit breaker, thus providing greater flexibility of operation between these four generators. Generators No. 3, No. 6, and No. 9 and transformer banks No. 2, No. 3, and No. 5 may be double-bussed in the future should the 13.8-kv. ring be formed. This permits testing a line from a generator with the least interference to the maximum output over the remaining line or lines.

There will be two feeders, each connected to separate sections of the 13.8-kv. bus to supply a station service transformer bank, and provision for two other feeders for the supply to communities in the vicinity.

Two plans for the 220-kv. structure were considered: one a complete double bus layout which would have been located on the west shore, the other the most flexibly operated bus that could be located on the roof of the power house. On the basis of cost and operating convenience the latter was chosen, incorporating reserve oil circuit breakers for the lines.

The reserve line breakers are located at the ends of the 220-kv. structure and can be electrically substituted for the regular ones. Quick isolation of a defective section is provided for by several interlocked motor-operated bus sectionalizing air-break switches.

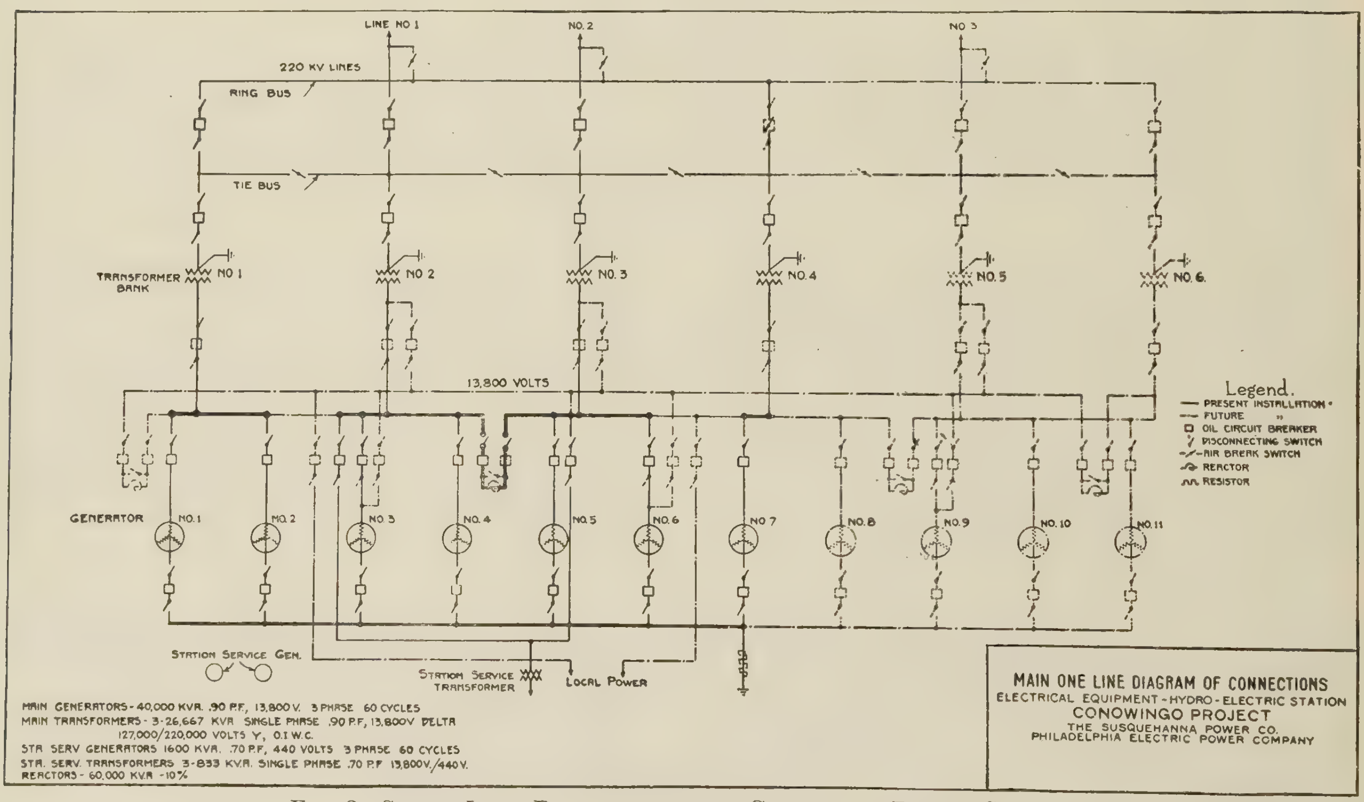

FIG. 2—SINGLE-LINE DIAGRAM OF THE CONOWINGO POWER STATION

transformer bank. Should it at some future time be deemed desirable for any reason to operate in parallel on the 13.8-kv. side, then, by means of additional construction, the various busses of this voltage may be tied together through reactors to form either a four-section ring bus or a three-section straight bus. Initially, the

Station Auxiliary System. Fig. 4 is a one-line diagram of the 440-volt three-phase auxiliary system. This may be divided into two parts: First, that to supply the essential auxiliaries of each main unit, which are air-exciter set, a governor oil pump and a generator ventilating fan. The energy is obtained from alterna-

tors directly connected with their exciters on the shaft of the main unit. Second, that to supply the less essential auxiliaries and the general lighting. The power is obtained from two 1600-kv-a. station service turbine generators and a 2500-kv-a. transformer bank. The latter is provided with an induction regulator on the 440-volt side.

The unit auxiliary bus is divided into two parts to increase the flexibility, and an emergency supply may be obtained from either individual feeders from the station service busses or a feeder common for all generators.

The general station service supply is from a single bus sectionalized into three sections, the middle one supplied by the transformer bank, and each of the two end ones by a turbine generator.

The lighting is obtained from three 200-kv-a., single-phase, 440/110-220-volt transformers, dividing the lighting into three independent parts. In the event of failure of the a-c. supply, a number of lighting circuits are automatically connected to a storage battery by a throw-over switch. Two 20-kv-a. series lighting transformers are installed for lighting the highway over the dam, and a transformer bank stepping up to 2300 volts, three-phase is used to supply service to the operating village near by. Air circuit breakers are used throughout.

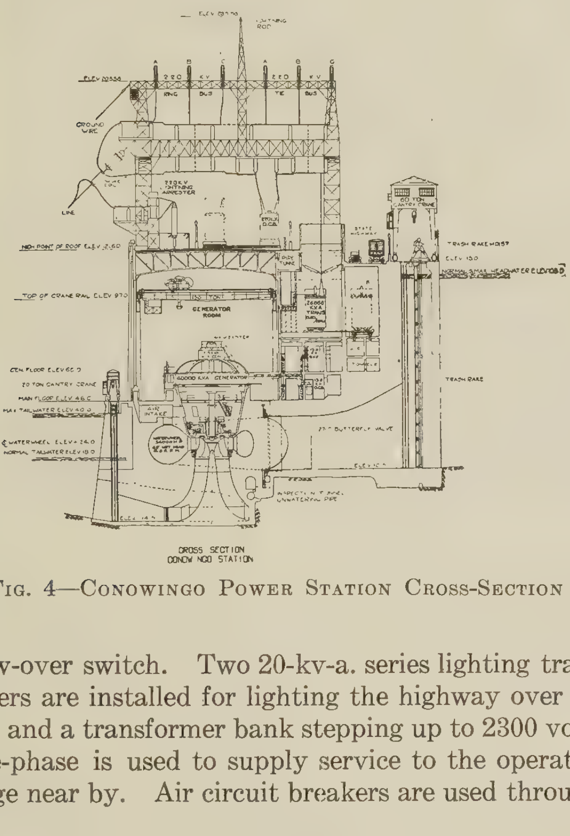

FIG. 4—CONOWINGO POWER STATION CROSS-SECTION

Excitation System. As noted above, each of the main generators is excited from individual motor-generator exciter sets. These consist of a 375-hp. induction motor, a 240-kw., 250-volt main exciter and a 10-kw., 250-volt pilot exciter operating at 1200 rev. per min. As high-speed excitation is essential for stability of operation, it was necessary to use motor-generator exciters instead of mounting these exciters on the same shaft with the main unit. The voltage regulator used is a combination of rheostatic and vibrating contact busses. This high-speed excitation has been described in the technical press.[2]

Provision has been made to switch the excitation circuits to a spare exciter driven from the general station bus in case of failure of the regular motor-generator exciter.

Main Generators. The main generators, physically the largest ever built, are rated 40,000 kv-a., 90 per cent power factor, 13,800 volts, three-phase, 60-cycles, 81.8 rev. per min. Directly-connected, above the thrust bearing, is a 715-kv-a., 70 per cent power factor, 440-volt, three-phase, 60-cycle auxiliary generator and its 41-kw., 250-volt exciter. The neutrals of both main and auxiliary generators are brought out, and in the case of the main generators are grounded through a four-ohm resistor common to all of the units. Fifteen temperature resistors are provided in the main machine. The generators are, roughly, 38 ft. in diameter, 32 ft. high, and weigh complete well over 500 tons.

Main Transformer Banks. Each main transformer bank is of 80,000-kv-a. capacity, consisting of three 26,667-kv-a. water-cooled units. They are *Y*-connected on the 220-kv. side, with solidly grounded neutral, are insulated for 187 kv. and have a 7½ per cent tap in this winding. The 13.8-kv. side is delta connected.

Oil Circuit Breakers. The oil circuit breakers for 220,000-volt service are rated 187 kv., 1000 ampere, 2,500,000 kv-a. rupturing capacity. Potential networks are attached to the condenser bushings which will supply potential for synchronizing and the operation of impedance relays and instruments.

The 13.8-kv. breakers have a rupturing capacity of 1,500,000 kv-a. They are rated 15 kv., but are insulated for 25 kv., as are also all the insulators and current transformers. The generators and light and power breakers are of 2000-ampere capacity, the bus tie of 4000-ampere capacity. They are motor-operated. The section of the station in which they are located is divided off into a number of smoke-proof compartments so that fire and the resulting soot will be confined to a comparatively small area.

Relays. The main generators have percentage differential relays which take care of phase-to-phase and phase-to-ground faults. Overvoltage and mechanical overspeed relays protect against excessive frequency and voltage that may occur upon sudden loss of load.

The unit auxiliary generators have differential relays, the station service generators and the service transformer have differential and overload protection.

The main transformers are equipped with differential relays and low-energy ground relays. Two additional overload relays provide protection against a 220-kv. bus failure between phases, and act as back-up relays for the phase-to-phase relays on the 220-kv. lines.

2. "Quick Response Excitation for Alternating-Current Synchronous Machines," C. A. Powel, *Electric Journal*, April 1927, p. 157.

The 13.8-kv. bus sections are protected by differential and low-energy ground relays.

The 220-kv. line breakers and the bus tie breaker are each provided with:

a. Three low-setting directional impedance relays to provide phase-to-phase protection,

b. Three instantaneous undervoltage relays,

c. Three instantaneous overcurrent relays,

d. One auxiliary relay whose contacts normally short circuit the current coils of the impedance relay

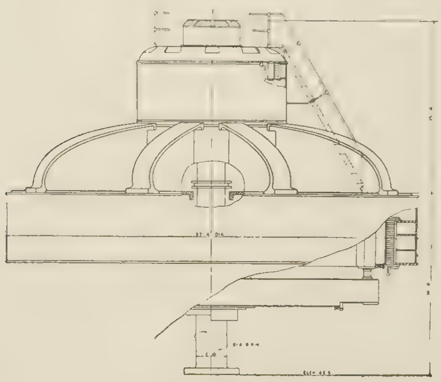

Fig. 6—40,000 Kv-a. Generator

(a), which is allowed to function by relay (b) or (c) if a fault occurs with minimum or maximum generating capacity, respectively.

Entirely separate from the relays described above are those installed for phase-to-ground protection. These are:

e. One inverse time directional relay. While this relay is entirely selective it is assisted and speeded by,

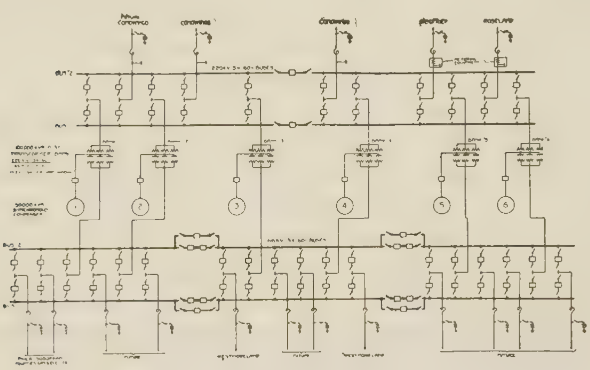

Fig. 7—Single-Line Diagram of Plymouth Meeting Substation

f. One plunger type instantaneous over-current relay, made directional by

g. One instantaneous directional relay whose contacts are in series with (f),

h. One low-energy ground relay acting as back-up.

It is to be noted that the transformer overload and ground relays are set selectively against the line impedance and ground relays.

Miscellaneous. The 220-kv. structure is unique, in that it contains the first installation of 220,000-volt lightning arresters ever made.

Communication with the Philadelphia load dispatcher is provided by direct and public telephone lines and low wavelength space radio.

Fire protection is provided by water lines, carbon tetrachloride extinguishers, and a portable Foamite generator. For additional protection there are two stationary Foamite generators which can be connected to a system by piping for fighting fires in the main step-up transformers.

The operating room is located at about the middle of the ultimate station and is provided with a pipe room beneath.

Control and emergency lighting of 250 volts is supplied

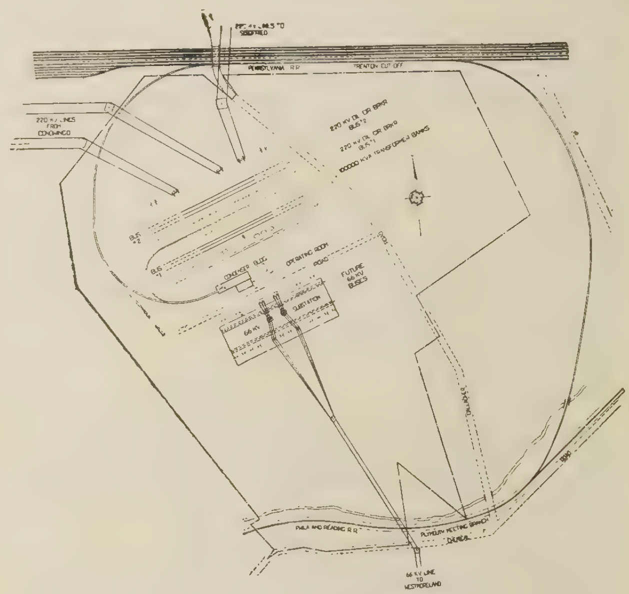

Fig. 8—Plot Plan of the Plymouth Meeting Substation

from two 632-ampere-hour storage batteries and three 15-kw. motor-generator sets.

In line with the company's standard practise, telephone drop signals are used to indicate any occurrence that should be brought to the operator's attention.

Oil handling is accomplished by means of two 500-gal. per min. pumps and five 12,000-gal. tanks.

Plymouth Meeting Substation

The location of this substation about 10 mi. northwest of the Westmoreland Substation was determined not only by the fact that it would be the terminus of the 220-kv. lines from Conowingo, but also those of the interconnection with the Pennsylvania Power and Light and Public Service Electric and Gas Companies.

The function of the station is to step-down the energy received over the above 220-kv. lines to 66 kv., and to provide for synchronous condensers used mainly for stability purposes. Fig. 6 is a single-line diagram and Figs. 7 and 8 show, respectively, the plan and cross-section of this substation. The area of land purchased for it is 40 acres.

The 220-kv. installation consists of two sectionalized busses, each line and transformer bank selecting either bus through oil circuit breakers. Provision is ultimately for seven lines and six transformer banks, of which three lines and two 130,000-kv-a. transformer banks are being installed at this time. The oil circuit breakers are rated 1000 amperes, 187 kv., 2,500,000 kv-a. rupturing capacity. Each of the two Conowingo lines is provided with three 132-kv. potential transformers connected between line and ground to be used for impedance relays as well as instruments. The Siegfried line is provided with three combined current and potential transformer metering units, the potential elements of which are also used for relays and instruments. Each line is provided with a 220,000-volt lightning arrester.

Step-down Transformer Banks. The initial installation consists of seven 43,333-kv-a., single-phase transformers making two 130,000-kv-a. banks with a spare. They have three windings; 220,000-volt Y, 66,000-volt Y, and 13,300-volt delta. The 13,300-volt tertiary serves the triple purpose of providing a closed delta for tap-changing under load and for driving synchronous condensers. The transformers with oil weigh 185 tons each. The tap-changing under load has a voltage range of 15 per cent and in addition, two 5 per cent taps are provided on the 220-kv. side.

The heavy oil circuit breakers and transformers, as well as the synchronous condensers, are handled by a simple system of tracks shown in Fig. 7. It is believed that on the initial installation alone the saving in handling heavy apparatus paid for the tracks and transfer cars.

66-kv. Substation. The 66,000-volt substation is of practically the same design as at Westmoreland and the description of this latter given below will suffice. The only exception is that all of the lines at Plymouth Meeting are overhead, whereas most of those at Westmoreland are underground. Provision is made, however, for taking any of the lines from Plymouth Meeting out underground. Lightning arresters are installed on all lines.

Synchronous Condensers. The condenser building is arranged to ultimately house six 30,000-kv-a. synchronous condensers. However, initially only three are being installed.

These condensers operate at 600 rev. per min. and are provided with a main 165-kw., 250-volt, six-pole, compound-wound exciter, and a 40-kw., 250-volt, six-pole, compound-wound pilot exciter, one mounted on each end of the same shaft.

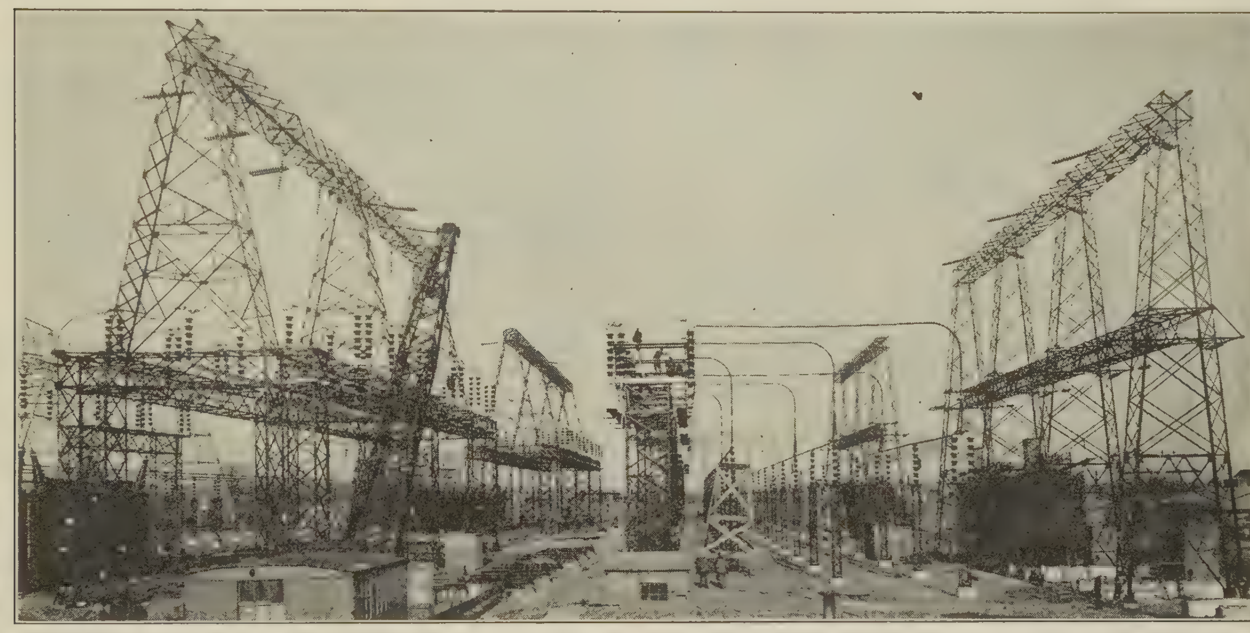

Fig. 11—General View of the 220-Kv. Yard During Construction

130,000-kv-a. transformer banks to the right, oil circuit breakers to the left.

The condensers at this location are to be used primarily for stability purposes. They are therefore provided with extra high-speed excitation, such as has been described in the technical press.[3] The armature voltage can be raised by the regulators at a rate of 6000–7000 volts per sec., applying a "ceiling" voltage of about 1000 on the nominal 250-volt field of the condenser. Normally it is planned to operate the condensers at about 10,000 kv-a, under certain conditions they will be able to deliver about 55,000 kv-a. each, and this increase of 45,000 kv-a. will be brought about in half a second.

To handle the large quantity of oil involved in this substation, a separate building has been erected,

3. "Super-Excitation," by D. M. Jones, *General Elec. Rev.*, Dec. 1927, p. 580; "Super-Excited Condensers," by O. A. Gustafson, *Elec. World*, Feb. 18, 1928, p. 349.

housing the centrifuges, blotter press, oil pumps and the system of valves and manifolds.

Relays. The relays for the 220-kv. lines are the same as those used at Conowingo, described above.

The 130,000-kv-a., three-winding transformer banks are provided with (a) three overload relays, and (b) three special percentage differential relays.

The 30,000-kv-a. synchronous condensers are provided with single-winding differentially-connected relays.

The 66-kv. lines are equipped with duplex directional impedance relays.

The station service transformer bank is protected by low-energy overload relays.

Westmoreland Substation

The Westmoreland Substation ties Conowingo and interconnection power into the Philadelphia Electric System. It consists of three parts; the 66-kv. substation, the 13.2-kv. substation, and the combined con-

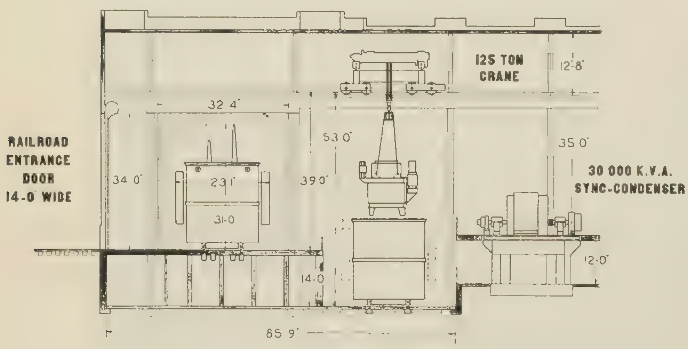

Fig. 13—Plymouth Meeting Substation
Method of handling 43,333-kv-a., 220-kv. transformers

denser building and operating room between them. This is shown in Fig. 11.

Fig. 13 is a cross-section of the substation. The 13.2-kv. design will be of the group-phase outdoor type of construction. It will be noted that the 66-kv. installation consists of double-bus construction, each sectionalized at two points and provided for the future installation of reactors at this point. To each of the three sections, two 100,000-kv-a. overhead lines from Plymouth Meeting will ultimately, be connected or a total of six; and in addition there is provision for a total of 13 50,000-kv-a. underground lines and four 80,000-kv-a. transformer banks stepping down to 13,200 volts. The initial installation will consist of two lines from Plymouth Meeting, two lines to the Richmond Generating Station and two lines to the Schuylkill Generating Station; also two lines extending to transformer banks at a near-by distribution substation, and two 80,000-kv-a. transformer banks. The oil circuit breakers are rated 800 and 1200 ampere, 73 kv., 2,000,000 kv-a. rupturing capacity. Lightning arresters are installed on the Plymouth Meeting lines. The relay protection consists of duplex directional impedance relays on all lines and differential with back-up overload relays on transformer banks.

The condenser building is laid out to house at present, two, and ultimately three 30,000-kv-a. synchronous condensers operating at 720 rev. per min. They will be connected to the 13,200-volt bus bars and will be started by means of auto-transformers. It was felt that the speed of excitation on these units need not be quite so fast as on those installed at Plymouth Meeting. However, fairly high speed is desired, and this is provided.

Both the 66-kv. and 13.2-kv. sections, as well as the condensers, are controlled from one operating room. In the same building is an extension in which provision will be made for a 300,000-volt kenotron test set, offices, battery rooms, etc. A 15,000-volt test set consisting of a transformer with ratio changing under load will be installed outdoors.

The 250-volt emergency lighting and control system consists of two 152-ampere-hour storage batteries and two 9-kw. motor-generator sets.

An oil-handling system consisting of pumps and filters is provided, together with 4500-gal. tanks. Supply and discharge pipe are extended conveniently to the 66-kv. breakers and directly to the transformers.

BUREAU OF STANDARDS JOURNAL OF RESEARCH

A new monthly periodical, the *Bureau of Standards Journal of Research* continues the publication of the two series of research papers heretofore issued in *Scientific Papers* and *Technologic Papers.*

The new journal will contain the bureau's research papers and critical reviews in the fields of science and technology. These will be comparable in interest and and importance with the bureau papers already issued. It is believed that the union of pure and applied science in one journal will tend to bridge the gap between the two fields, and in so doing, shorten the lag between discovery and application. This makes it the more desirable that all engaged in scientific or technical work should have the new publication available for current use and permanent reference. The new journal will be about the size of the *Philosophical Magazine* or the *Annalen der Physik.* Each volume (semiannual) will be indexed and a cumulative consolidated index will be included in the bureau's list of publications as heretofore.

Several hundred researches are in progress at the Bureau of Standards and the outlet for the results is the *Bureau of Standards Journal of Research.*

Address all orders and inquiries to Superintendent of Documents, Government Printing Office, Washington, D. C.

Abridgment of

The Conowingo Hydroelectric Development on the Susquehanna River

BY ALEX. WILSON 3rd[1]

Associate, A. I. E. E.

Synopsis.—The unusual features of the design and construction of the dam, power station, and hydraulic equipment, together with a general description of the entire project, are included in this article.

THE Conowingo Hydroelectric Development ranks as one of the largest in the United States, as shown by the following table giving installed capacities in other large plants:

Plant	Owner	Installed horsepower
Niagara Falls	Niagara Falls Power Company	452,500
Conowingo	The Susquehanna Power Company	378,000*
Muscle Shoals	United States Government	260,000*
Holtwood	Pennsylvania Water and Power Company	158,000
Keokuk	Mississippi River Power Company	150,000

*Initial Installation.

The Conowingo site, with a firm power value of but 30,000 kw., will initially deliver in Philadelphia 1,250,000,000 kw-hr. annually, resulting in an annual saving of more than 750,000 tons of coal; and with the present shape of the daily load curve of The Philadelphia Electric Company system, it can be relied upon for a minimum peak capacity of 180,000 kw., which would otherwise have to be provided ultimately in steam plant capacity.

From the standpoint of speed of construction, Conowingo is an outstanding achievement in the history of projects of similar size. Construction work was started March 8, 1926, under Federal License approved February 20, 1926, and on March 1, 1928, less than two years after starting construction, two of the seven 36,000-kw. main units of the initial installation were placed in regular operating service.

The Susquehanna River

With the exception of the St. Lawrence, the Susquehanna River basin is the largest and most important on the Atlantic Coast. It has a total area of 27,400 sq. mi.

Along its lower section the river has cut its way through a range of tableland; its bed is walled by steep rocky bluffs on either sides, affording excellent foundation conditions for water-power developments. A portion of the fall in this section has been developed by the Pennsylvania Water and Power Company's dam at Holtwood, Pennsylvania. The Conowingo Dam will utilize the head from the Holtwood tail-race to within four miles of tidewater.

Relocation of Highways and Railroad Required

The Conowingo Dam and Power House are located in Cecil and Harford Counties, Maryland, about six miles from the Mason and Dixon line and four and one-half miles upstream from the town of Port Deposit. The reservoir above the dam has an area of 14 sq. mi., and extends above the dam a distance of 14.5 mi. Relocation of 16 mi. of the Columbia and Port Deposit Branch of the Philadelphia, Baltimore and Washington Railroad Company operating on the left bank, together with numerous county and township roads, and one state road, including a steel bridge crossing the river at Conowingo, Maryland, two miles above the dam, were made necessary by the impounding of the waters in the reservoir. A new highway bridge with 20-ft. wide roadway supported on the structure of the dam and power house has been provided.

Site of Dam

At the site of the Conowingo Dam, the hills on both sides of the river form natural abutments. The river bed and its banks to a height well above the reservoir level are of igneous formation. Core borings drilled along the line of the upstream face of the dam to depths varying from 5 ft. to 100 ft. below the rock ledge all showed firm hard rock for their entire length.

As the main channel of the river ran along the Harford County shore, the power house has been located at that end of the dam.

Design of Dam and Headworks

The dam is of solid concrete masonry construction, designed as a gravity section. Its total length, 4648 ft., includes the power house headworks, 950 ft. long and 2385 ft. of ogee type gate-controlled spillway section. To collect seepage water under the dam and prevent excessive uplift, a longitudinal drain was installed on the foundation 10 ft. 6 in. downstream from the face of the dam. Cross drains spaced 45 ft. on centers connect this drain to tail water at the toe of the dam. At all vertical construction joints riser drains connect the bottom drains to the inspection tunnel. To reduce seepage through the vertical construction joints, copper sealing strips were installed near the upstream face of the dam. Grout holes located 2 ft. inside the upstream face of the dam were drilled in the foundation to a depth of 20 ft. at 10 ft. intervals and grouted under 25-lb. pressure to form a cut-off wall against seepage through the foundations.

The dam and power house are founded on rock at an

1. Construction Engineer, Philadelphia Electric Co., Philadelphia, Pa.

Presented at the Regional Meeting of the A. I. E. E., District No. 2, Baltimore, Md., April 17-20, 1928. Complete copies upon request.

average elevation of about 12 ft. above sea level for the dam, and 7 ft. for the power house.

The overhanging crest is an unusual feature of the spillway section. This permitted a curved surface, approximating the lower nappe of an overflowing stream of the depth of 22.5 ft. to be formed without increasing the width of the section beyond that required for stability.

The crest of the main spillway is fixed at elevation 86 and is surrounded by 50 Stony type movable crest gates, each 22.5 ft. high by 41 ft. wide, operating in guides provided in concrete piers on the dam. Three regulating gates, each 10 ft. high by 41 ft. wide, have been provided adjacent to the power house on a fixed crest at elevation 98.5 for use in finer regulation of the pool level. In the design of the spillway, an allowance of 4000 lb. per linear foot was assumed, for ice pressure at the water surface. The gate piers, spaced 45 ft. on centers, continue up above the pool level and support a runway at elevation 115, extending along the spillway section and power house headworks from which three electrically operated gantry traveling cranes operate the crest and regulating gates as well as the sectional head gates and trash racks on the power house. The gate piers also support the highway bridge which has replaced the old Conowingo Bridge inundated in the reservoir.

The spillway section for the three regulating gates and 17 crest gates has been provided with a 20-ft. wide apron, curving up from the toe of the dam to an angle of 12½ deg. with the horizontal, in order to prevent erosion at the toe of the dam.

Power House Structure

The substructure of the power house, designed to meet the requirements of the waterways required by the hydraulic units and to support the superimposed loads of the water-wheels and power house superstructure, was constructed of reinforced concrete. A maximum depth of foundation excavations to elevation minus 20.5 ft. was required at the hydraucone draft tubes of the Allis-Chalmers Manufacturing Company wheels. Where Moody spreading type draft tubes were used on three of the units, excavation was carried to elevation 16.5 ft. below sea level. The main power station superstructure of the initial installation includes the generator room, which is about 70 ft. wide by 75 ft. high by 650 ft. long. The electrical bay between the generator room and headworks is a two-story building containing the 13,800 volt bus and switch compartments. Compartments for step-up transformers are located on the roof of the electrical bay, together with the main control room and the station service control room, from which, windows afford a direct view of the generator room. The 220-kv. switching station is located on the roof of the generator room. For the purpose of assembling such large parts as the generator rotors and water-wheel runners a dismantling area has been provided at the shore end of the power station. An office bay has been constructed between the power house and shore and is equipped with an elevator operating between elevation 35 and the reception room, at the elevation of the highway bridge.

Hydraulic Equipment

Initial installation provides for seven 54,000-hp. Francis runner, vertical-shaft water-wheels, (ultimately to be increased to 11 such units) operating under a normal head of 89 ft. and at 81.8 rev. per min. each, direct-connected to a 40,000-kv-a., three-phase, 60-cycle, 13,800-volt generator. These water-wheels, generators, and valves, in physical dimensions, are the largest constructed to date.

There are also two 1900-hp. station service units.

The shape of the intake was determined largely by the use of butterfly valves as head gates for the water-wheels, which permitted the intakes to be designed with a wide entrance near the bottom of the river and low entrance velocity, which is accelerated uniformly to a maximum in the scroll case. The intake of each main unit is divided into two sections by a vertical reinforced concrete wall, extending to within 22.5 ft. of the center line of the butterfly valve. Guides for steel head gates and sectional trash racks have been provided at the entrance, together with guides for a mechanical trash rake which operates on rails on the headworks.

Water-wheels No. 1, 2, 5, and 6 were furnished by the Allis-Chalmers Manufacturing Company and are connected to General Electric Company generators. Wheels Nos. 3, 4, and 7 were furnished by the I. P. Morris Corporation and drive Westinghouse generators. As the runners of the different manufacturers are interchangeable, only one spare runner is required. The governors are of the actuator type with fly-balls driven through gearing from the main shaft and are operated by oil pressure cylinders. There is one oil pressure system for each pair of units. An oil storage and purification system has been provided for all of the governors and bearing oil of all units, including station service units. With each main water-wheel unit, a 27-ft. diameter vertical shaft, butterfly valve, complete with operating equipment, oil pressure system, and accessories, has been installed at the water passages to the runners. These valves have a cast steel housing and a wicket of cast steel, a forged steel shaft and a plate steel penstock liner, extended 12 ft. upstream in the intake passage. These valves are operated by oil pressure from a central oil pressure system. All butterfly valves and the plate steel scroll cases to which they are attached have been furnished by the same manufacturers as the respective water wheel units on which they have been installed. The weight of the rotating elements, together with hydraulic thrust, is carried by the thrust bearings on top of the generators. These bearings are supported by bracket arms extending radially from the structural steel pit liner, which also supports the stator of the generator. In the generators furnished by the General Electric Company, a spring type thrust bearing has been used. The Westinghouse generators have Kingsbury thrust bearings.

River Diversion and Construction Methods

At the beginning of the work, a progress schedule was carefully worked out to determine the progress necessary to be made by the various operations of the work to coordinate these operations with the scheme of river diversion. This schedule contemplated operation of the first two units on June 1, 1928. Construction progress, however, was considerably better than scheduled, with the result that two units started commercial operation on March 1, and a third unit a few days later.

In the low water season of 1926, a cofferdam of the puddle-chamber type was constructed, enclosing the power house and west branch of the tail race, an area of about 14 acres. The top of this cofferdam was built to elevation 42, at which elevation it was estimated that it would not be topped by any flood of less volume than 350,000 cu. ft. per sec., so that work on the heavy excavation of the power house foundations and draft tubes could reasonably be expected to proceed without interruption by floods in the spring of 1927. Simultaneously with the construction of the power house cofferdam, another cofferdam of the spaced crib type was constructed from the Cecil County shore, extending to within approximately 700 ft. of the power house cofferdam. About the middle of November, a flood of 350,000 sec-ft., the greatest November flood that has been recorded for the Susquehanna River, occurred. The head water elevation raised to within a few inches of the top of the sand bags which had been placed on the power house cofferdam and of course, topped the spaced crib cofferdam on the other side of the river. As the foundations for the dam had been completed in this area with alternate spillway sections each, including two bridge piers poured to a height above the river level, it was not necessary to again unwater this cofferdam after the flood had subsided.

During the winter and early spring of 1927, the pouring of the pier sections was completed up to and including the highway bridge, leaving intermediate sections 38 ft. wide at the level of the foundation (elevation 22) to provide for the diversion of the river during the summer of 1927. Likewise the power station headworks was completed during this period up to an elevation well above flood levels.

As soon as the spring floods of 1927 had sufficiently subsided, the cofferdam was extended from the last completed spillway section to the power house headworks, and by September, the foundations of the dam had been completed in this last cofferdam and the alternate sections poured above the elevation of the top of the cofferdam. With the removal of this cofferdam, twenty 38-ft. wide notches in the spillway, together with eight 10-ft. high by 18-ft. wide sluices through the spillway, were taking care of the river flow.

Final closure of the notches was commenced early in October, 1927. The easterly ten notches were first brought up to elevation 30, and the west ten to elevation 35. These two groups, with a 5-ft. difference in bottom grades, were then raised alternately in 10-ft. lifts, thus providing 5-ft. flow through ten openings in addition to the flow through the eight sluices. In the actual closing of the waterway at each 38-ft. opening, a steel and timber flap gate, hinged at the top from the adjoining spillway sections, was used. The gantry cranes, provided for the crest gates, were used to handle these flap gates. With the raising of the notches and corresponding rise of the headwater level, the discharge capacity of the eight sluices increased so that finally when the notches had been raised to about elevation 50, the discharge from the sluices was equal to the river flow and the closing of the notches was completed without the use of the flap gates.

After the concrete in the notches had been completed to crest elevation, final closure of the eight sluices was made by lowering specially designed, reinforced concrete gates, weighing 75 tons each, and then filling the sluiceway opening with concrete.

Closure of the notches was hampered through November and December 1927 by high water. Favorable flow conditions occurred in January, however, permitting completion to crest elevation on January 16, and on January 17, 1928, the sluiceway gates were dropped, making the final closure of the dam.

For the construction of the dam, a steel work trestle with deck at elevation 60 was built on the toe of the dam. Three self-propelled, electrically-operated gantry travelers, each equipped with a 15-ton steel derrick and concrete elevator were used, the travelers operating on rails at the sides of the trestle deck and being designed to allow clearance for cars operating on the three standard-gage tracks also provided on the trestle deck.

The following quantities involved in the construction of the dam and power house will be of interest:

Cofferdam cribs	4,250,000 cu. ft.
Rock excavation, including tail race	348,000 cu. yd.
Forms	3,850,000 sq. ft.
Concrete	660,000 cu. yd.
Structural steel	9,500 tons
Reinforcing steel	6,400 tons
Hydraulic machinery	6,500 tons

A maximum working force of 5300 men was employed on the Project.

The contract for the design and construction of the dam and power station, including installation of hydraulic machinery and 13,800-volt electrical equipment was awarded to Stone and Webster, Inc. The Arundel Corporation, as subcontractors to Stone & Webster, constructed the dam and were also awarded the contract for the relocation of the tracks of the Columbia and Port Deposit Railroad. Contract for design and construction of the 220-kv. switching station on roof of generator room and the transmission lines was awarded to Day and Zimmerman Engineering and Construction Company.

Acquisition of all lands required by the Project and all negotiations with Federal, State, and County Commissions were conducted by the power companies direct. All matters of design and construction were also under the general supervision of the power companies.

Abridgment of

Power Supply for Railway Signals and Automatic Train Control

BY C. F. KING, Jr.[1]

Associate, A. I. E. E.

Synopsis.—This paper deals, in a general way, with the several systems of automatic block signaling, particularly the a-c. system, and the apparatus commonly used to insure continuity of power supply. It covers briefly the older phases of the subject and more specifically the later applications.

The most modern system of continuous inductive train control, the code system, has required the development of frequency-converting apparatus for this use. Within the past three years, a number of frequency-converting automatic substations has been installed by the railway companies. The class of apparatus used in these stations is discussed, including some details of installations on the Pennsylvania and Long Island Railroads.

AUTOMATIC block signaling on railroads has reached a high degree of perfection. Within the last few years train accidents due to failures of signals to operate properly have been practically unknown. Developments were started many years ago but perhaps the greatest impetus toward developing and applying the automatic signals came in 1922 when the Interstate Commerce Commission ordered 45 railroads each to equip one locomotive division with automatic train control or train stop. In 1924 a second order was issued calling upon 41 of the original 45 carriers to equip a second locomotive division. These two orders covered approximately 15,000 track mi. and 6300 locomotives. All of this work has been completed.

The experience gained in this widespread use of the automatic system has been very valuable and has led to the development of the modern reliable signal equipment.

The most important early development was the adoption of the closed-track-circuit principle. In this system absence of current in the track causes indication of the low-speed or stop signal. This makes for safety and this principle is the basis of all modern systems.

For a-c. signaling the track circuit consists of the rails, rail bonds, track relay, and track transformer. For d-c. signaling, primary cells or storage cells take the place of the track transformers.

There are also two combination systems using both alternating current and direct current known respectively as the a-c. floating-battery system and the a-c. primary-battery system. These systems utilize direct current for the track circuit under all conditions. Normally, alternating current is used for the lamps which give the position-light and color-light signals. If the alternating current fails the lamps are connected quickly to a battery by means of an automatic change-over switch or "power-off" relay. There is, in effect, an automatic substation of the order of 150-volt-amperes capacity at each signal location.

1. General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Presented at Pacific Coast Convention of the A. I. E. E., Spokane, Wash., Aug. 28-31, 1928. Complete copies upon request.

The fundamentals of these systems and the fundamentals of the d-c. system are such as to provide excellent insurance against signal outages due to power failures, if the batteries are properly maintained.

A-c. signaling owes its development to the application of automatic signaling on d-c. electric-traction systems and to difficulties encountered on steam railways caused by interference with d-c. track circuits by stray currents from nearby d-c. circuits.

For the operation of a-c. signals the practise is to provide a power line paralleling the railway. At each signal location the line voltage is stepped down to the proper voltage for the track circuit, relays, lamps, and semaphore mechanisms.

Power for operating the early a-c. signal systems was provided by means of steam-engine or turbine-driven alternators operated by the railways. The switching was performed manually and two attendants were always on duty, one to fire the boilers and one in charge of the engine room. When synchronizing the alternators, the fireman manipulated the throttle and the engineer operated the switchboard. These power plants were located along the right-of-way, consideration being given to the division of load among the the stations and the possibility of locating the signal apparatus in plants, such as shop power plants, where the labor was already available.

At the present time railway companies realize the advantages of purchasing power from central station companies with the result that the isolated plants are rapidly being replaced by unattended automatic substations supplied from power company lines.

It is well known that the cost of central station electric power has declined during the past decade. Public utility lines have been extended so that power can be purchased in almost any locality. Outages of considerable duration are exceptional. At the same time the cost of generating power in isolated plants has increased.

Automatic switchgear may be obtained to perform practically any function that can be performed manually and to do it more reliably and more quickly. Switchboard operators may, therefore, be eliminated.

To provide a degree of reliability for a-c. signaling

comparable with the reliability of systems using batteries, it is necessary to provide two sources of power supply for each section of signal line. These sources of supply are usually at opposite ends of the line and the switchgear provides for one of the sources to be feeding at all times and for the other to be connected quickly to the line upon failure of the normal or preferred source. Protective relays are provided which make it impossible for both sources to be connected to the line at the same time, also low-voltage protection to disconnect the signal line from the source of supply in the event of loss of voltage on the supply, and over-current relays to disconnect the signal line from the supply in the event of heavy overloads on the signal line.

The signal power supply on the Florida East Coast Railway between Jacksonville and Miami is an excellent example of this type of installation. Over the 366 route miles between Jacksonville and Miami, eight automatic substations are located. Between Jacksonville and Daytona Beach the voltage is 4400, and between Daytona Beach and Miami the signal line voltage is 2200.

A large majority of the present automatic train control and train stop installations are of the intermittent inductive type or the continuous inductive type. The intermittent inductive type is effective only at wayside signal locations. No power is required for the wayside elements, or inductors as they are called. The continuous inductive type provides continuous cab-signal indications. It is effective regardless of the location of the train in the block. It makes use of a track circuit superimposed on the wayside-signal track circuit.

The code system is the latest development of the continuous inductive system. In this system the receiving circuits on the locomotives are "tuned" so that they will respond only to energy supplied at a certain frequency. To eliminate the possibility of interference from commercial power circuits a nominal frequency of 100 cycles has been widely selected as the most favorable frequency for the track-circuit current.

Railways using the code system are the Pennsylvania, the Long Island, the West Jersey and Seashore, the Central of New Jersey, the Reading, the New York, New Haven & Hartford, and the Delaware, Lackawanna and Western. Some of these present interesting track-current conditions. The Long Island has direct current for propulsion, 25-cycle current for wayside signals, and 100-cycle current for automatic train stop. The Pennsylvania between Altoona, Pa. and Harrisburg, Pa. has 60 cycles for wayside signals and 100 cycles for train stop, and on the Pan Handle Division, Pittsburgh, Pa. to Newark, Ohio, 100 cycles for both signals and train stop. The D. L. & W. uses direct current for wayside signals and 100 cycles for train stop between East Buffalo, N. Y. and Elmira, N. Y., and 100 cycles for both wayside signals and train stop between Elmira and Johnson City, N. Y.

Rotating apparatus must be provided to change from 25-cycle, 60-cycle, or d-c. primary supply to 100-cycle output. The machines may consist of d-c. motors, synchronous motors, single-phase or polyphase induction motors driving synchronous alternators, or of induction motors driving induction generators.

With the exception of very unusual conditions (as on the Long Island which will be described later) the choice is usually between (a) squirrel-cage induction motors driving synchronous generators with direct-connected exciters and (b) squirrel-cage motors driving induction generators.

Induction generators cost less than synchronous generators. Part of the power output is obtained by transformer action between the stator and rotor of the generator. With a 60 to 100-cycle conversion, 60 per cent of the power output is obtained by transformer action and the driving motor need be large enough to supply only the remaining 40 per cent plus the friction and windage. There are characteristics, however, such as low-power factor, changes in secondary voltage in direct proportion to changes in primary voltage, and inability to adjust the voltage over a wide range by means of a rheostat as can be done with a synchronous generator, that probably will limit the induction type to the smaller ratings and to applications where the high-frequency track circuit is used for train control only.

One of the divisions ordered by the Interstate Commerce Commission to be equipped with automatic train control was the Pan Handle Division of the Pennsylvania Railroad. This division extends from Pittsburgh, Pa. west to Newark, Ohio. It consists of 158 route miles and 375 track miles over which there are operated an average of 233 trains a day.

For this division the code system of continuous inductive train stop with "forestaller" was adopted. Four locomotive cab-signal indications were provided, the three fundamental signals, *viz.*, "proceed," "proceed with caution," and "stop," and a fourth signal indicating that the approach to the next block must be made at restricted speed. To "forestall" an automatic brake application each change in the cab signal indicating a less favorable condition ahead, must be acknowledged by the engineman within six seconds. The acknowledgment is made by momentarily reversing a conveniently located switch and then returning it to normal.

At the same time the automatic train stop was installed, manually operated and d-c. semaphore signals were replaced with a-c. position-light signals.

To provide 100-cycle energy for the wayside signals and automatic train stop, eight automatic substation equipments were installed. The accompanying diagram, Fig. 1, indicates the relative locations of the equipments.

At Newark, Coshocton, and Dennison 60-cycle energy is purchased from the Ohio Power Company and the equipments are located in Ohio Power Company substations. At Weirton Junction and McDonald, power

is purchased from the West Penn Power Company, the equipment at McDonald being located in a substation of the power company. At Pittsburgh, power is purchased from the Duquesne Light Company. Substations were built along the right-of-way to house the equipments at Pittsburgh and Weirton Junction. The railroad company has a large freight locomotive terminal at Scully and the facilities include a power plant with generating apparatus. This provided an excellent location for one of the signal-power apparatus units.

At all of the above mentioned stations the frequency-

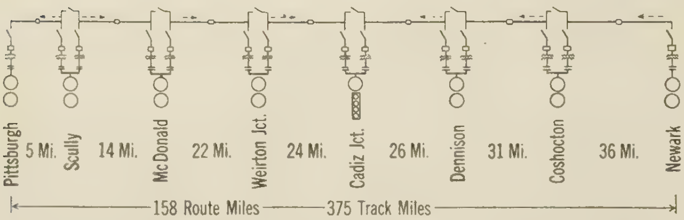

FIG. 1—ARRANGEMENT OF AUTOMATIC SIGNAL SUBSTATIONS PAN HANDLE DIVISION, PENNSYLVANIA RAILROAD SYSTEM

converting apparatus consists of a 75-hp., 2200-volt, three-phase, 60-cycle squirrel-cage induction motor direct-connected to a generator rated 60 kv-a. 80 per cent power factor, 220 volts, 100 cycles at 1200 rev. per min. single-phase with a direct-connected exciter. The motors were designed to carry full load with normal voltage impressed on their terminals with a slip of not more than two per cent of synchronous speed. This insures an output frequency of not less than 98 cycles.

An exception to the rule regarding the purchase of current from public utility companies was encountered at Cadiz Junction, where satisfactory service was not available. Therefore, a gasoline-engine-driven generator was installed. The engine develops 100 brake hp. at 1000 rev. per min. The generator is rated 50 kv-a., 80 per cent power factor, 220 volts, single-phase, 100 cycles, 12 poles. A 15-hp., 100-volt starting motor, operating from a storage battery, cranks the engine and brings it up to speed before the engine takes the load. The motor is located between the engine and the generator. The exciter is direct-connected to the other end of the generator shaft.

Several schemes of operation are possible with the apparatus provided for the Pan Handle Division. The scheme that was decided upon as offering the most advantages from both the economic and operating viewpoints was for all stations, except Cadiz Junction and Pittsburgh, to be in service under normal conditions. Newark feeds east to Coshocton; Coshocton feeds east to Dennison and Dennison feeds east to Cadiz Junction. Weirton Junction feeds west to Cadiz Junction, McDonald west to Weirton Junction. Scully feeds west to McDonald and east to Pittsburgh. At all stations the 100-cycle voltage is stepped up to 6600 volts for transmission, a pole line having been built the length of the division for the special purpose of taking care of this single-phase power line.

If the voltage fails on the line between Newark and Coshocton the contactor on the west feeder panel at Coshocton instantly closes and restores voltage. In like manner a voltage failure between Coshocton and Dennison provides the impulse for instantly closing the signal-line contactor on the west feeder panel at Dennison. The gasoline engine generator set at Cadiz Junction is used only for emergency service. It is, like the motor-generator sets, fully automatic in operation. Starting impulse is received in the event of a voltage failure on the signal line between Cadiz Junction and Dennison or Cadiz Junction and Weirton Junction. It starts and takes the load in less than six seconds. A line-voltage failure between Weirton Junction and McDonald causes the contactor on the east feeder panel at Weirton Junction to close instantly. A failure at Scully causes the east feeder contactor at McDonald to close and provides the starting impulse for the emergency motor-generator set at Pittsburgh. A clapper-operated oil switch connects the motor to the 65 per cent tap of an auto-transformer for starting and a solenoid-operated oil switch (the solenoid being energized from the exciter) connects the motor to full voltage. Starting in this manner it requires, depending principally upon bearing temperatures and voltages of the primary supply, from five to six seconds to restore voltage to the signal line. The motors are started through auto-transformers. They were designed, however, for full voltage starting under which condition the time required to restore voltage on the signal lines could be reduced somewhat.

Transfer of load from any station to an adjacent station may be made in less than one second. For example, to transfer the load on the Newark Station to Coshocton it is necessary only to depress a button on the feeder panel at Newark causing the signal-line contactor to open. The loss of voltage on the signal line, as previously stated, provides the closing impulse for the west feeder contactor at Coshocton.

In the event of signal-power line trouble it is important to segregate the defective section as quickly as possible. On the Pan Handle Division a pole-mounted oil circuit breaker is located approximately midway between each pair of adjacent substations. These breakers are set to open instantly on short circuit. If a short circuit occurs on the side of the breaker farthest away from the station feeding the section, the breaker opens instantly and sectionalizes the line. If the trouble occurs between the breaker and the station feeding the line, the line contactor on the feeder panel opens after an appreciable time depending upon the setting of the controlling relay. The loss of voltage provides the closing impulse for the corresponding feeder contactor in the adjacent station. The instant this contactor closes the oil circuit breaker opens and sectionalizes the line. At the west end of the division,

where the traffic is relatively light as compared with the east end, there is a possibility of 18 mi., or half the distance between Newark and Coshocton, being out of service due to line trouble. Eastward the distances are shortened until, between Scully and Pittsburgh, there is a possibility of 2.5 mi. being automatically segregated because of line trouble.

Manually operated, two-way disconnecting switches are located one at each signal location for further sectionalizing the line. The signals average approximately one per mile east of Dennison and one for every five to ten thousand feet west of Dennison.

Additional flexibility is obtained by the use of a two-pole, manually remote-controlled, gang-operated pole-top disconnecting switch at each substation which provides means for tying together any two adjacent sections of the power line.

With generating apparatus, such as is used on the Pennsylvania, supplying current for both signals and train control, automatic voltage regulators are used. Overvoltage does not make for a dangerous condition in so far as the train control is concerned but it does provide a dangerous condition in connection with the operation of the wayside signals. This is because overvoltage may provide so much current in the track circuit that sufficient current will not be shunted by trains to deenergize the track relays. If automatic voltage regulators are not properly maintained the contacts may, in time, stick, which will result in excessive voltage. Provision should be made for either automatically removing the generator from service or automatically inserting a fixed resistor in the exciter field sufficient to reduce the voltage to a safe operating value.

Provision is made for opening the signal-line contactors on short circuit. If the station is an end station, such as Newark or Pittsburgh, and, therefore, has only one line contactor, the motor-generator set will shut down and will be automatically locked out of service if the contactor opens due to short circuit. If the station has two feeders, both line contactors must be opened before the machine will be automatically locked out of service.

Another modern installation of automatic signals is located on a branch of the Long Island Railroad. This installation is interesting on account of one unusual feature as already mentioned. The unusual feature consists of a d-c. driving motor in the motor-generator set instead of the more usual a-c. motor. It was not possible here to use an a-c. motor because the frequency of the main a-c. supply varies so much that the signal frequency would vary beyond the permissible limits of 96 and 100 cycles.

In this installation the Long Island Railroad has automatic train stop between Jamaica and Babylon, a distance of 27.6 mi. An alternator for providing 100 cycles is located in each of the substations which house the electric-traction synchronous converters at Babylon, Lynbrook, and Jamaica. Lynbrook is 8.3 mi. east of Jamaica and 19.3 mi. west of Babylon. The motor-generator sets at Babylon and Lynbrook are four-unit machines. The driving motor is rated 20 hp., 650 volts, direct current. It is direct-connected to the 100-cycle alternator, an exciter, and a pilot generator. The alternator is rated 15 kv-a., 220 volts, single-phase, 100 cycles at 1500 rev. per min. The exciter is rated 1 kw., 125 volts. The pilot generator is rated 0.5 kw., 250 volts direct current.

The receiving circuits of the steam locomotives and multiple-unit cars are tuned for best results at 98 cycles. The efficiency of reception decreases as the frequency changes in either direction from normal, the permissible limits of frequency being 96 and 100 cycles. The motors are operated from the 650-volt d-c. busses which also supply energy for the multiple-unit cars. As the bus voltage may vary between 450 and 700 a speed regulator had to be provided. The pilot generator operating in conjunction with a simple and sturdy vibrating regulator accomplishes the desired results.

Under normal operating conditions the alternator at Lynbrook feeds east to Babylon and west to Jamaica. The 100-cycle voltage is stepped up to 2200 volts for transmission. The alternators at Babylon and Jamaica are for emergency service only. The switching in all stations is performed manually. As attendants are present to supervise the electric-traction synchronous converters and as all stations receive their primary 25-cycle energy from the same source, little benefit would be obtained from automatic switchgear.

Conclusion

Automatic block signals are established firmly as necessities on those railways where they are installed and where operations are planned so as to take advantage of the safety and dispatch which the signals provide. Relatively simple, automatic substations used in conjunction with the a-c. systems, when the frequency of the signal energy is the same as the frequency of the primary supply, will be employed in increasing numbers as signaling systems are extended.

The future of the frequency-converting substation is not as certain. The 100-cycle current is primarily for train-control operation. All of the installations ordered by the Interstate Commerce Commission have been completed. Whether additional orders will be issued and whether the carriers on their own initiative, will make additional installations are open questions. In any event, the frequency-changing motor-generator sets in ratings of 1.5 kv-a. to 60 kv-a. and the accompanying switchgear, that have been installed in the past three years, are interesting additions to the steadily increasing electrical facilities of our railway transportation systems.

Parallel Resonance and Anti-Resonance

BY W. J. SEELEY*

Associate, A. I. E. E.

THERE seems to be a certain amount of uncertainty among authors as to just what is a correct definition of resonance in a parallel circuit such as shown of Fig. 1. The most common definition is that resonance is that condition which makes the total reactance, or susceptance, equal to zero. This is the condition for unity power factor. In some definitions the further condition is added that at resonance the total impedance of the circuit is a maximum. The A. I. E. E. Standardization Rules,[1] for instance, say that resonance

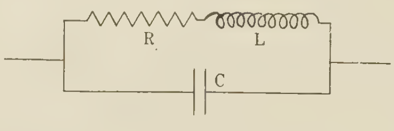

FIG. 1

is the condition of maximum impedance obtained by varying L or C, and nothing is said about zero reactance or unity power factor. These differences in definitions have led to this investigation.

The term *Parallel Resonance* will be used in this paper to define that condition existing among the elements of a parallel circuit, (Fig. 1), which makes the resulting reactance, or susceptance, equal to zero. And *Anti-Resonance* will be used to define that condition which makes the impedance a maximum. The term anti-resonance has been borowed from telephone parlance[2] and is used by telephone engineers to indicate the condition of maximum impedance. The purpose of this paper is to investigate what relations, if any, exist between these two conditions. For a series circuit they are identical, but for a parallel circuit they are identical only under certain conditions.

The absolute magnitude[3] of the impedance of the circuit of Fig. 1 is given by equation (1),

$$Z = \sqrt{\frac{R^2 + \omega^2 L^2}{R^2\,\omega^2\,C^2 + (\omega^2\,L\,C - 1)^2}} \tag{1}$$

The reactance is given by equation **2**,

$$X = -\frac{\omega\,[L - C\,(\omega^2\,L^2 + R^2)]}{R^2\,\omega^2\,C^2 + (\omega^2\,L\,C - 1)^2} \tag{2}$$

which reduces to equation (3) when set equal to zero,

$$\omega^2\,L^2\,C - L + R^2\,C = 0 \tag{3}$$

In accordance with the definition adopted above, equation (3) must be satisfied if the circuit is to be in parallel resonance. The usual method of adjusting the circuit for parallel resonance is to vary either ω, C, or L, holding everything else constant, until equation (3) is satisfied. Equations (4), (5), and (6) give the values of ω, C, and L, respectively, which must obtain to give the resonant condition. These values are obtained by solving equation (3). Equation (**4a**) gives the commonly used value of ω for parallel resonance. If the value of ω as given in equation (4) is substituted in equation (1), the result will be the total impedance of the circuit when resonance is obtained by varying

TABLE I

Adjusted element	Parallel resonance		Anti-Resonance			
	Value of adjusted element	Resulting Z	Exact value of adjusted element	Maximum Z (exact)	Approx. value of adj. element	Maximum Z (approx)
ω	$\sqrt{\frac{1}{L\,C} - \frac{R^2}{L^2}}$ (4)	$\frac{L}{R\,C}$ (7)	$\sqrt{\frac{\sqrt{1+2\,R^2\,\frac{C}{L}}}{L\,C} - \frac{R^2}{L^2}}$ (10)	$\sqrt{\frac{L/C}{2\,\sqrt{1+2\,R^2\frac{C}{L}} - \left(2+R^2\,\frac{C}{L}\right)}}$ (13)	$\sqrt{\frac{1}{L\,C} - \frac{R^2}{L^2}}$ (16)	$\frac{L}{R\,C}$ (19)
	$\sqrt{\frac{1}{L\,C}}$ (4a)	$\frac{1}{R\,C}\sqrt{R^2\,L\,C + L^2}$ (7a)			$\sqrt{\frac{1}{L\,C}}$ (16a)	$\frac{1}{R\,C}\sqrt{R^2\,L\,C + L^2}$ (19a)
C	$\frac{L}{\omega^2\,L^2 + R^2}$ (5)	$\frac{\omega^2\,L^2 + R^2}{R}$ (8)	$\frac{L}{\omega^2\,L^2 + R^2}$ (11)	$\frac{\omega^2\,L^2 + R^2}{R}$ (14)	$\frac{1}{\omega^2\,L}$ (17)	$\frac{\omega\,L}{R}\sqrt{\omega^2\,L^2 + R^2}$ (20)
L	$\frac{1 + \sqrt{1 - 4\,R^2\omega^2C^2}}{2\,\omega^2\,C}$ (6)	$\frac{1 + \sqrt{1 - 4\,R^2\,\omega^2\,C^2}}{\omega^2\,C^2(1 - \sqrt{1 - 4\,R^2\,\omega^2\,C^2}}$ (9)	$\frac{1 + \sqrt{1 + 4\,R^2\,\omega^2\,C^2}}{2\,\omega^2\,C}$ (12)	$\sqrt{\frac{1 + \sqrt{1 + 4\,R^2\,\omega^2\,C^2}}{\omega^2\,C^2\,[\sqrt{1 + 4\,R^2\,\omega^2\,C^2} - 1]}}$ (15)	$\frac{1}{\omega^2\,C}$ (18)	$\frac{1}{R\,\omega^2C^2}\sqrt{R^2\,\omega^2C^2 + 1}$ (21)

*Asso. Prof. of Elec. Engg., Duke University, Durham, N. C

1. See end of article for all references.

TABLE II

$\omega = 10 \times 10^6$

R	ω P. R. (4)	ω exact A–R (10)	ω approx. A–R (16)	ω approx. A–R (16a)	Z P. R. (7)	Z exact A–R (13)	Z approx. A–R (19)	Z approx. A–R (19a)
0	10×10^6	10×10^6	10×10^6	10×10^6	∞	∞	∞	∞
5	10	10	10	10	0.2×10^6	0.2×10^6	0.2×10^6	0.202×10^6
10	10	10	10	10	0.1	0.1	0.1	0.1005
20	10	10	10	10	0.05	0.05	0.05	0.051
40	10	10	10	10	0.025	0.025	0.025	0.0269
60	10	10	10	10	0.0167	0.0167	0.0167	0.0194
80	9.96	10	9.96	10	0.0125	0.0125	0.0125	0.0160
100	9.94	10	9.94	10	0.0100	0.0100	0.0100	0.0140

R	C P. R. (5)	C exact A–R (11)	C approx. A–R (17)	Z P. R. (8)	Z exact A–R (14)	Z Approx. A–R (20)
0	100×10^{-12}	100×10^{-12}	100×10^{-12}	∞	∞	∞
5				20×10^4	20×10^4	20×10^4
10				10	10	10
20				5	5	5
40				2.5	2.5	2.5
60				1.67	1.67	1.67
80				1.25	1.25	1.25
100				1.00	1.00	1.00

R	L P. R. (6)	L exact A–R (12)	L approx. A–R (18)	Z P. R. (9)	Z exact A–R (15)	Z approx. A–R (21)
0	1×10^{-4}	1×10^{-4}	1×10^{-4}	∞	∞	∞
5	1	1		200×10^3	200×10^3	200005
10	1	1		100	100	100000
20	1	1		50	50	50000
40	0.998	1.0016		22.3	25	25000
60	0.996	1.0036		15.77	16.7	16680
80	0.993	1.0064		11.91	12.5	12560
100	0.9895	1.01		9.69	10.05	10500

TABLE III

$\omega = 5 \times 10^3$

R	ω P. R. (4)	ω exact A–R (10)	ω approx. A–R (16)	ω approx. A–R (16a)	Z P. R. (7)	Z exact A–R (13)	Z approx. A–R (19)	Z approx. A–R (19a)
0	5000	5000	5000	5000	∞	∞	∞	∞
5	4995	5000	4995		2000	2000	2000	2005
10	4975	5000	4975		1000	1000	1000	1010
20	4900	5000	4900		500	500	500	510
40	4580	4970	4580		250	269	250	269
60	4000	4880	4000		167	196	167	194
80	30	4660	30		125	162	125	160
100	0	4270	0		100	147	100	142

R	C P. R. (5)	C exact A–R (11)	C approx. A–R (17)	Z P. R. (8)	Z exact A–R (14)	Z Approx. A–R (20)
0	2×10^{-6}	2×10^{-6}	2×10^{-6}	∞	∞	∞
5	1.995	1.995		2005	2005	2002
10	1.98	1.98		1010	1010	1005
20	1.92	1.92		520	520	510
40	1.73	1.73		290	290	269
60	1.47	1.47		227	227	195
80	1.22	1.22		205	205	160
100	1.00	1.00		200	200	141

R	L P. R. (6)	L exact A–R (12)	L approx. A–R (18)	Z P. R. (9)	Z exact A–R (15)	Z approx. A–R (21)
0	0.02	0.02	0.02	∞	∞	∞
5	0.01995	0.02005		1997	2005	2002.5
10	0.01980	0.0202		995	1005	1005
20	0.01917	0.0208		480	476	510
40	0.016	0.0228		200	285	270
50	0.01	0.0241		100	241	223
60		0.0256			214	187
80		0.0289			180	160
100		0.0324			111	141

the frequency (ω). This is given by equation (7). Likewise, equations (8) and (9) give the resulting impedance when resonance is obtained by varying C and L respectively. Equation (**7a**) gives the value of the impedance corresponding to equation (**4a**). In other words, equations (7) to (9) give the values of the total impedance of the circuit when it is adjusted to parallel resonance by varying ω, C, or L.

Anti-resonance is obtained by solving equation (1) for a maximum, by the ordinary method of differential calculus, using ω, C, and L as variables. Equations (**10**), (**11**), and (**12**) give the values of ω, C, and L, respectively, which will give maximum impedance, and equations (**13**), (**14**), and (**25**) give the values of these maximum impedances. Equations (**16**), (**16**a), (**17**), and (**18**) give the approximate or commonly used values of ω, C, and L for anti-resonance, and equations (**19**), (**19**a), (**20**), and (**21**) give the resulting maximum impedances.

For easy comparison, all the algebraic expressions for the two conditions of resonance are collected together in Table 1 and the following facts are to be noted:

1. For ω as variable, the expression for parallel resonance is identical with the approximate expression for anti-resonance.
2. For C as variable, the expression for parallel resonance is identical with the exact expressions for anti-resonance.
3. For L as variable, there is no correspondence whatever.
4. If R were zero, there would be exact correspondence in all cases and the two conditions would be identical; ω, C, and L would have the values given by equations (**16a**), (**17**), and (**18**); and in all cases the impedances would be infinity.

However, R is never zero, and the conclusion is that algebraically, at least, the two conditions are not identical, and it is incorrect to define resonance in a parallel circuit as the condition for both zero reactance and maximum impedance.

A few authors do indicate that they are not the same. Magnusson,[4] for instance, calls attention to the two

TABLE IV

$\omega = 377$

$\frac{L}{C} = 1421$

R	ω P. R. (4)	ω exact A–R (10)	ω approx. A–R (16)	ω approx. A–R (16a)	Z P. R. (7)	Z exact A–R (13)	Z approx. A–R (19)	Z approx. A–R (19a)
0	377	377	377	377	∞	∞	∞	∞
5	373	377	373		284	289	284	286.7
10	363	376	363		142	146.6	142	147.2
20	319.5	371	319.5		71	84.2	71	80.4
40	0	310.7	0		35.5	54.5	35.5	51.8
60	↑	0	↑		23.7	62.8	23.7	44.6
80		↑			17.8	∞	18.8	41.7
100					14.2	↑	14.2	40.3
	$R = 37.7$	$R = 58.55$	$R = 37.7$	↓		$R = 75.4$		

R	C P. R. (5)	C exact A–R (11)	C approx. A–R (17)	Z P. R. (8)	Z exact A–R (14)	Z Approx. A–R (20)
0	70.4×10^{-6}	70.4×10^{-6}	70.4×10^{-6}	∞	∞	∞
5	69.2	69.2		289.6	289.6	266
10	65.8	65.8		152.1	152.1	147
20	54.9	54.9		91.1	91.1	80.5
40	33.1	33.1		75.5	75.5	51.7
60	19.9	19.9		83.6	83.6	44.5
80	12.8	12.8		97.7	97.7	41.6
100	8.8	8.8	↓	114.2	114.2	40.5

R	L P. R. (6)	L exact A–R (12)	L approx. A–R (18)	Z P. R. (9)	Z exact A–R (15)	Z approx. A–R (21)
0	0.1	0.1	0.1	∞	∞	∞
5	0.098	0.101		278.4	287.3	285
10	0.092	0.106		131.5	153.4	147
20	0.05	0.123		37.7	87.2	80.8
40	↑	0.167		↑	59.4	51.8
60		0.217			51.3	44.4
80		0.268			49.9	41.6
100		0.320			45.4	40.3
	$R = 18.85$		↓	$R = 18.85$		

TABLE V

$\omega = 377$

$\frac{L}{C} = 128$

R	ω P. R. (4)	ω exact $A-R$ (10)	ω approx. $A-R$ (16)	ω approx. $A-R$ (16a)	Z P. R. (7)	Z exact $A-R$ (13)	Z approx. $A-R$ (19)	Z approx. $A-R$ (19a)
0	377	377	377	377	∞	∞	∞	∞
5	338	374	338	↓	25.6	27.86	25.6	27.96
10	176	341	176		12.8	17.46	12.8	17.05
20	0	0	0		6.4	17.66	6.4	12.98
40	↑ $R = 11.31$	↑ $R = 17.58$	↑ $R = 11.31$		3.2	24.37	3.2	11.75
60					2.1	∞	2.1	11.51
80					1.6		1.6	11.41
100					1.3		1.3	11.39

R	C P. R. (5)	C exact $A-R$ (11)	C approx. $A-R$ (17)	Z P. R. (8)	Z exact $A-R$ (14)	Z Approx. $A-R$ (20)
0	234.6×10^{-6}	234.6×10^{-6}	234.6×10^{-6}	∞	∞	∞
5	196.2	196.2	↓	30.59	30.59	28
10	131.6	131.6		22.79	22.79	17
20	56.85	56.85		26.40	26.40	12.8
40	17.37	17.37		43.20	43.20	11.8
60	8.05	8.05		62.13	62.13	11.5
80	4.60	4.60		81.60	81.60	11.4
100	2.96	2.96		101.28	101.28	11.4

R	L P. R. (6)	L exact $A-R$ (12)	L approx. $A-R$ (18)	Z P. R. (9)	Z exact $A-R$ (15)	Z approx. $A-R$ (21)
0	0.030	0.030	0.030	∞	∞	∞
5	0.022	0.035	↓	18.72	29.95	28.0
10	0.015	0.046		11.32	19.22	17.1
20	↑ $R = 5.66$	0.070		↑ $R = 5.66$	14.97	13.18
40		0.122			13.02	11.76
60		0.175			12.42	11.52
80		0.228			12.14	11.45
100		0.280			11.97	11.38

expressions for frequency and calls one "unity power-factor frequency," and the other "maximum current resonance frequency." Morecroft[5] also distinguishes between the two frequencies.

Each of the equations in Table 1 was tested numerically to see whether there might be numerical identity. Calculations were made for three values of ω, 10 by 10^6, 5 by 10^3, and 377, and for values of R ranging from zero to 100 ohms. Two calculations were made for $\omega = 377$, one for $L/C = 1421$, and the other for $L/C = 128$. In the first case, $L = 0.1$ henry, $C = 70.359$ by 10^{-6} farad; and in the second, $L = 30$ by 10^{-3} henry, and $C = 234.5$ by 10^{-6} farad. The results are given in Tables 2, 3, 4, and 5.

As a result of this investigation, the following conclusions may be made:

1. At radio frequencies, for resistances below 100 ohms, parallel resonance and anti-resonance are identical when ω or C are the variables, and practically identical when L is the variable.

2. At radio frequencies for resistances below 100 ohms, the commonly used expressions for ω, C, L, and Z will yield very nearly correct results.

3. At all frequencies, parallel resonance and anti-resonance are identical when C is the variable.

4. At low frequencies, parallel resonance and anti-resonance are not identical, except as noted in conclusion 3. The larger the ratio of L to C, the nearer they approach identity.

5. At radio frequencies, the values of the impedances are nearly alike for ω, L, or C as variables, but at lower frequencies they are quite different.

References

1. A. I. E. E. Standardization Rule No. 13027.

2. Transmission Circuits for Telephonic Communication, by K. S. Johnson, p. 174.

3. The equations **1**, **2**, and **3** can be found in any standard text on alternating currents or they can very easily be derived.

4. Electric Transients, p. 187.

5. Principles of Radio Communication, p. 94 of second edition.

Abridgment of

Electrical Communication

ANNUAL REPORT OF COMMITTEE ON COMMUNICATION*

To the Board of Directors:

The Committee on Communication submits the following report as a summary of the progress which has been made in the electrical communication art during the past year.

Printing Telegraphs

There has been continued growth in the use of printing telegraph instruments. In addition to the applications for police service mentioned under another heading, it may be noted that more than 800 circuits connecting main and branch officers of the telegraph companies are now equipped with printers.

The tendency to reduce manual operations as much as practicable has been quite pronounced in ocean cable telegraphy during recent years. Recent developments in this direction were described in a paper entitled *Printing Telegraphs on Ocean Cables* which was presented by H. Angel at the 1927 Summer Convention of the Institute.

The automatic tape transmission system for telegraph tickers which was mentioned in the 1926 and 1927 reports has been further extended during the past year, so that full market quotations are now available to practically all sections of the United States.

Telegraph Repeaters

Many of the repeaters now used on long telegraph circuits, both in land line and ocean cable service, are of the regenerative class. A description of one type of regenerative repeater and an outline of operating experience with it was given in A. F. Connery's paper on *A Non-Rotary Regenerative Telegraph Repeater* presented at the 1927 Summer Convention.

Rather important advances have been made in the simplification of circuit and equipment arrangements for telegraph repeaters installed in central telegraph offices.

Telegraph Transmission Theory

A paper entitled, *Certain Topics in Telegraph Transmission Theory* was presented by H. Nyquist at the 1928 Winter Convention of the Institute. In addition to presenting a quantitative statement of certain fundamental telegraph requirements, this paper presented for the first time an analysis of the fundamental problems involved in single sideband carrier telegraph transmission which may offer important economies in frequency range under some conditions.

Cord Carriers for Telegrams

For some years past, most large telegraph offices have been equipped with mechanical conveyers, usually of the moving-belt class, for the transfer of telegrams from one part of the operating room to another. A multiple cord carrier system has recently been developed which is proving very satisfactory for such conveying service.

Dial Telephony

The rapid application of dial telephone systems has continued. During the year, about 500,000 dial telephone stations were installed, bringing the total in service in this country, as of the first of January 1928, to approximately 2,900,000 stations, or about 16 per cent of the total telephones in service.

A paper entitled, *Some Recent Developments in Dial Systems*, by W. E. Farnham and H. M. Bascom, was presented at the evening session of the Student Convention and New York Section Meeting, April 19, 1928.

The dial system of operation has been extended to service from one suburban point to another suburb of the same city. This matter was discussed in a paper entitled, *Tandem System of Handling Toll Calls in and About Los Angeles*, by E. Jacobson and F. D. Wheelock, which was presented at the 1927 Pacific Coast Convention of the Institute.

Toll Telephone Service

During the year, telephone toll service was established between the United States and a number of important cities in Mexico, including Mexico City, Tampico, Monterey, Saltillo, San Luis Potosi, Puebla, and others. The service was inaugurated by an exchange of greetings between President Coolidge and President Calles at the capital cities of the two republics over a circuit 3360 mi. long. The service from Mexican points was further extended to points in Canada by the end of 1927.

Telephone Toll Cables

The extension of the network of toll telephone cables throughout the country continued at an increased rate during the year 1927, about 2000 mi. of cable being installed.

At the present time, 7,500,000 telephones of the Bell System have direct access to the toll cable network in the northern and eastern parts to the country which

---

*COMMITTEE ON COMMUNICATION:

H W. Drake, Chairman,

G. R. Benjamin,	S. P. Grace,	F. A. Raymond,
H. P. Charlesworth,	Erich Hausmann,	Chester W. Rice,
F. J. Chesterman,	P. J. Howe,	C. A. Robinson,
L. W. Chubb,	F. H. Kroger,	J. K. Roosevelt,
J. L. Clarke,	R. H. Manson,	H. A. Shepard,
C. E. Davies,	R. D. Parker,	J. F. Skirrow,
R. D. Evans,	S. R. Parker,	H. M. Turner,
E. H. Everit,	H. S. Phelps,	K. L. Wilkinson,
D. H. Gage,		F. A. Wolff.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

provides within that area toll service which is relatively immune from the effects of storms.

Planning Extensions to Telephone Plant

The problems involved in the planning of telephone plant and descriptions of the telephone plant in various regions were discussed in a number of papers presented at Institute meetings. The principal 1927 papers were as follows: *Advance Planning of the Telephone Toll Plant,* by J. N. Chamberlain, presented at the Pacific Coast Convention; *Telephone Toll Plant in the Chicago Region,* by Burke Smith and G. B. West, presented at the Chicago Regional Meeting; and *Planning Telephone Exchange Plants,* by W. B. Stephenson, presented at the St. Louis Regional Meeting, 1928.

Communication Apparatus and Materials

The application of permalloy to communication problems continued during the year. Interesting information regarding this material was given in a paper entitled, *Manufacture and Magnetic Properties of Compressed Powdered Permalloy,* by W. J. Shackleton and I. G. Barber, which was presented at the Winter Convention, 1928.

A paper entitled, *Recent Developments in the Process of Manufacturing Lead-Covered Telephone Cable,* by C. D. Hart, was presented at the Chicago Regional Meeting.

Electrical Transmission of Pictures

While no new stations have been added to the telephotography network of the Bell System (Boston, New York, Atlanta, Cleveland, St. Louis, San Francisco, and Los Angeles), interest in the service is increasing greatly and it is becoming much more important to the press.

Television

At a joint Annual and New York Section Meeting in New York with a talk on television was given by Dr. H. E. Ives, followed by a demonstration at the Bell Telephone Laboratories. Also a symposium on television at the Detroit Summer Convention was led by Dr. Ives followed by demonstrations. The symposium included notable papers entitled: *The Production and Utilization of Television Signals,* by F. Gray, J. W. Horton, and R. C. Mathes; *Synchronization of Television,* by H. M. Stoller and E. R. Morton; *Wire Transmission of Television,* by D. K. Gannett and E. I. Green, and *Radio Transmission of Television,* by E. L. Nelson.

Carrier-Current and Superimposed Systems

During the year there was a marked increase in the use of carrier-current systems in commercial telephone and telegraph plant, including a new system of a simplified nature which provides a single channel and is applicable economically to distances as short as 75 mi. The total length of carrier telephone circuits added during the year was approximately 65,000 channel mi.

In the application of carrier telegraph arrangements over 125,000 two-way channel miles were added to the Bell System during the year. This includes channels obtained from open-wire facilities by carrier frequencies above the voice range as well as voice-frequency carrier telegraph channels obtained from circuits in long toll cables. The increase is approximately evenly divided between the two types.

The application of carrier-current telephony to communication over power lines has increased steadily until at the present time there are in this country alone, 298 fixed stations in operation. Recent improvements in these systems have been along the lines of interconnecting them with private telephone systems. Portable and semi-portable carrier communication apparatus is being successfully used in conjunction with fixed stations.

Utilization of carrier current for other than communication purposes is rapidly increasing. The applications are for control of street lights, pilot protection of transmission circuits, supervisory control of substations and similar equipment, telemetering, etc.

Some recent developments in carrier current and other superimposed systems were described in the following papers presented at Institute meetings during the year, 1927:

The Use of High Frequency Currents for Control, by C. A. Boddie, Summer Convention.

A Carrier-Current Pilot System of Transmission Line Protection, by A. S. Fitzgerald, Pacific Coast Convention.

Coupling Capacitors for Carrier-Current Applications, by T. A. E. Belt, Pacific Coast Convention.

Supervisory Control Apparatus

In the power field, elaborate supervisory and control arrangements are now available by which an operator can control switches or other apparatus at distant points, and by means of currents transmitted back from the distant point determine the conditions which exist there. The Westinghouse Company reports that development work is being started on a form of such supervisory control apparatus, which is of interest in the communication field as it is intended to operate at frequencies in the voice range which can be transmitted over telephone circuits. The work has not yet reached the point where the possibilities and limitations of the system can be determined. Demonstrations of a preliminary model of the apparatus under the name "Televox" have, however, created considerable popular interest from the fact that the operation of such an arrangement over telephone circuits can be thought of as simulating conversation between persons.

Transatlantic Radio Telephony

The opening of transatlantic telephone service between the United States and England was covered in last year's report. The service was improved by the completion of a radio receiving station at Cupar,

Scotland, which is located as far north as conveniently possible for the purpose of reducing interference caused by atmospheric disturbances.

The time during which service normally is available has now been extended to 14½ hr., the period of service extending from 5.30 a. m. to 8.00 p. m., eastern standard time. The service was extended to Cuba and to five cities in Canada as well as to various cities of Continental Europe.

The outstanding event which took place during the period covered by this report was the holding of a joint meeting of two organizations on opposite sides of the Atlantic for the first time in history. This was a joint meeting of the Institute during the Winter Convention in New York with the British Institution of Electrical Engineers in London.

Preliminary to the joint session, a paper entitled, *Transatlantic Telephony—The Technical Problem,* was, presented by O. B. Blackwell, and a paper entitled, *Transatlantic Telephony—The Operating Problem,* was presented by K. W. Waterson.

The joint session was preceded by the opening of communication from New York by Mr. Charlesworth who spoke to Colonel Lee in London. The telephone was then turned over to President Gherardi and to President Page of the British Institution of Electrical Engineers. After an exchange of greetings, brief addresses were given by Dr. F. B. Jewett and General John J. Carty from this side of the water and by Colonel Purves and Sir Oliver Lodge from London.

At various times during the year the transatlantic telephone service was discussed at a number of sectional meetings.

International Radio Conference

The international Radio-Telegraph Conference held in Washington in 1927 achieved several very important agreements affecting International radio communication. The delegates were faced with the responsibility of expanding an agreement made several years ago, mainly with a view to facilitating the use of radio in marine communication service. Since that agreement had been written, the use to radio had expanded to telephone as well as telegraph service and the field had widened to embrace in addition to the marine communication service, aids to navigation such as compass and beacon, aircraft and other new mobile services, point-to-point services, amateur and experimental work, and broadcasting. The new agreement had to apply to this much wider field of use without hampering the progress and development of the art. The most important achievements were the following:

The agreement on the assignment of frequency bands for services in the whole radio spectrum.

The recognition of the fact that every type or method of transmission of necessity occupies a definite frequency band or channel.

The agreement that interference to other services is the controlling limitation put upon the method of using a frequency channel.

The recognition of the amateur status in the international communication field.

The progressive suppression of the use of damped waves. No new installations using damped waves may be set up for land and fixed stations and the use of such waves at existing stations is forbidden after January 1, 1935. On ship and aircraft stations, new damped wave installations may be made only if such apparatus uses less than 300 watts on full power, and the operation of these damped wave installations is forbidden after January 1, 1940. Thus in 12 years the history of damped waves will close.

The agreement upon the use of an automatic alarm signal in the marine service.

The setting up of an International Technical Consulting Committee.

Radio Broadcasting

Comparisons of results obtained by operating a broadcasting station with power outputs up to 100 kw. have established, fairly definitely, the essentials of this important subject.

Short-wave broadcasting and re-broadcasting in the U. S. and foreign countries has developed gradually with considerable recent improvements. These are mainly due to the utilization of sufficient power to provide dependable service and to improvements in the reception of short waves which have been almost exclusively used for this purpose.

Recent demonstrations of transmissions and receptions of both still pictures (facsimile)and moving objects (television), utilizing broadcasting transmitters, have indicated the probable future extensive application of these features to the present broadcasting service.

Other Radio Communication

During 1927 short wavelengths were first utilized to provide a commerical service designed to maintain contact between the home office and ships making around-the-world tours. Such a service was applied also to ships plying between the United States and the far East where the distances are very great.

The percentage of long distance communication handled by short waves increased further during 1927. In the United States there were installed on several long distance radio circuits, the Radio Corporation of America's projector system. This system has been in use a sufficiently long period to demonstrate that it is a large factor in making it possible to obtain an economical long distance radio communication service. This projector system includes not only directive transmission but also directive reception. The directive reception differs from the transmission in that several receiving antennas directive in themselves, are spaced

in such a manner as to eliminate the momentary fading which previously had so limited the use of short waves. With this method of receiving short waves it is possible to obtain a record so free from multilation as to be practically perfect. Thus, in a way not anticipated some years ago, there has been accomplished the elimination of the effect of static.

The development and application of radio transmissions to aid in guiding aircraft has made rapid progress during the year.

Railroad train radio telephone equipment has been developed for front-to-rear communication on long freight trains. The apparatus provides telephonic communication and call signals between the locomotive and the caboose under all conditions whether the train is standing or in motion, and even when the train is broken if the separation does not exceed four or five miles. A four months test of the equipment was recently successfully completed on the James River Division of the Chesapeake and Ohio Railroad.

For cases in which the expense of the above mentioned telephone system cannot be justified, a signal system of lower power has been developed for service between front and rear of long freight trains. It provides only for call signals and telephonic communication is not possible.

Radio telephone equipment for railroad hump-yard service has been developed to facilitate the classification of freight cars at congested terminal points. The apparatus is similar to the train radio-telephone equipment, except that it is of lower power. The apparatus provides one-way telephonic communication between the yard-master's office and any locomotive in the yards.

Sound Reproduction

Improvements were made in the design of loudspeakers as regards efficiency, power and uniformity over the speech frequency range. Some of the advances in design by which these improvements have been obtained were discussed in a paper entitled, *Loud Speakers of High Efficiency and Load Capacity*, by C. R. Hanna, presented at the Winter Convention, and in a paper entitled, "A High Efficiency Receiver for a Horn-Type Loudspeaker of Large Power Capacity," by E. C. Wente and A. L. Thuras, which was published in the *Bell System Technical Journal* for January 1928.

A paper entitled, *Electrical Reproduction from Phonograph Records*, by E. W. Kellogg, presented at the Detroit Summer Convention, discussed some interesting mechanical and electrical problems encountered in the development of improved reproducing devices.

Fire and Police Signal Systems

Further refinements of apparatus have been introduced in fire alarm systems during the past year. Improved automatic repeaters have recently come into use, the operation of which closely accords with the rules of the National Fire Protection Association requiring complete non-interference between coincidental signals, so that succession devices in street boxes will function, whether the boxes are on the same or on different circuits of the system.

In a new type of puncturing register, the paper punchings are folded under instead of being detached, thus eliminating much objectional paper dust; the instrument requires less power for its operation and runs at a higher speed than earlier registers.

Another improvement is the use of radio for communicating from fire alarm headquarters to moving apparatus, such as fire chiefs automobiles or fire boats. Boston has had such a broadcasting station for the past two years. It operates on a short wave, and has been found highly effective in sending orders to fire boats when absent from their regular berths. New York has recently experimented with a similar system.

In police signaling, an important development is the increasing use of telautographs and telegraph printers for interstation communication. These systems have been found useful in quickly and accurately spreading the news of hold-ups, automobile thefts, and other crimes. They have been found especially valuable where used in connection with the flashlight system of calling the patrolmen to the street signal boxes. A rather extensive installation of printing telegraph instruments made during the past year for the New York Police Department illustrates the expansion of service of this character. This system is so arranged that an operator at headquarters may send signals from a keyboard to any one precinct, to any group, or simultaneously to all precincts, the messages being printed automatically in page form at receiving machines placed close to the desks of officers in charge of precincts. Facilities are provided so that the receipt of the message may be acknowledged by each station. Another interesting system of this kind is in Connecticut, where police headquarters in twelve important cities are interconnected by telegraph printer circuits. It is expected that by the end of 1928 the system will be so extended that practically all of the cities in the state will be covered.

Several conflicting tendencies are noted in traffic signaling, particularly with respect to the colored lights or equivalent devices employed. While the green-amber-red cycle of signals has been adopted by many cities, others have favored either more or less complex arrangements. Centralized control of the street signals is being extended and while difficulties are experienced in so synchronizing operations as to minimize hazards and delays, it seems likely that this problem will ultimately be solved.

H. W. Drake,
Chairman.

Radio Acoustic Position Finding in Hydrography

BY JERRY H. SERVICE*

Associate, A. I. E. E.

Synopsis.—*In hydroelectric surveys it is difficult to fix the positions of the soundings when the survey ship is beyond the range of visibility of shore objects; the radio-acoustic method is designed to help in meeting this difficulty. Temporary shore stations are set up, each equipped with a microphone placed in the water in a known position and connected with an amplifier ashore through a cable; the amplifier is in turn connected through a relay to an automatic key driven by clockwork, which causes a radio transmitter to send out a characteristic signal whenever the microphone is disturbed.*

When the position of the ship is wanted, a small bomb is fired in the water alongside the ship; the instant of the explosion is automatically recorded on a chronograph aboard the ship. The sound of the explosion disturbs the shore station microphone and the resulting characteristic radio signals of the shore stations are received on board the ship and also recorded on the chronograph. Thus the ship obtains the time of travel of sound in water from her position to each of the shore station microphones, which are in known positions. The speed of sound in sea water being known, the ship's position is thus fixed. The method has been used successfully in the U. S. Coast and Geodetic Survey with the ship 75 mi. or more away from the shore stations.

A device for quick plotting on the field sheet is described. The accuracy of the method is discussed.

Introduction

In hydrographic surveys, the fundamental objective is the production of accurate nautical charts for the guidance of mariners. Soundings in great number and well distributed over the area surveyed must be taken. These soundings must be accurate as to depth, but it is just as important that the positions of the soundings should be accurately known. That is to say, a survey ship while taking soundings must know her position accurately at all times.

So long as the ship is within the range of visiblilty of shore objects, natural or artificial, such as mountain peaks, tall chimneys, elevated tanks, prominent lone trees, or specially constructed signals, the problem is comparatively easy in the daytime and in clear weather. At regular short intervals, angles between the right and center, and center and left objects, are simultaneously measured with sextants by two observers on board the ship; these two angles can be set up on a three-arm protractor, or "station pointer," and the ship's position can be plotted within a minute of time.

But at night (except in those rare instances in which three well located lights can be identified), in foggy weather, or when the ship is beyond the range of visibility of shore objects, the problem becomes difficult. Dead reckoning, in which the ship's position is fixed by her distances run (measured by the patent log or the revolution counter) in the directions as given by her compass, with allowances for current and leeway (due to the ship being blown sidewise through the water by the wind), is always open to question. Formerly, when the ship had to stop for every sounding, dead reckoning was especially questionable; now, with the advent of echo sounding, by means of which the ship can run continuously at full speed, dead reckoning is much more satisfactory than it was. Astronomical fixes, even when taken at their best on stars at morning and evening twilight by several observers, have comparatively large probable errors and are limited to a few times per day, and then only when the sky is clear and the horizon is well defined.

If some means could be devised that would locate a survey ship accurately, at frequent intervals, day or night, clear weather or foggy, in rough weather or in smooth, and as far off shore as she might have occasion to work, it may be seen that such a method, if its cost were not excessive, would be very useful.

The British have such a method,[1,2] in which the pressing of a key on board the ship simultaneously detonates a small charge of explosive in the water near the ship and sends out a radio dash. A station on shore records on an Einthoven galvanometer photographic recorder, the time of arrival of the radio dash and also the times of arrival of the sound wave from the explosion at each of a number of hydrophones suitably disposed in known positions on the sea bed. What they get is the distance of the explosion from each hydrophone, and the bearing of the explosion from the mid-point of each pair of hydrophones. The use of the bearing lines in connection with the range lines makes considerable accuracy possible. The shore station transmits the position of the explosion to the ship by radio. Very little equipment is required on board the ship, so that the method is of use in navigation. It is stated that with a 9-oz. charge of explosive, locations can be given within a range of 40 mi. from the hydrophones.

In 1923 the U. S. Coast and Geodetic Survey, in collaboration with the Sound Laboratory of the U. S. Bureau of Standards, worked out a method of locating a survey ship by radio-acoustic methods.[3] While some important practical modifications in details have been made during the past five years, this method is still used with no changes in the general principle. Since 1925 it has been proved economical and successful in the waters off the Pacific Coast of the United States especially in the waters off Washington and

*Junior Hydrographic and Geodetic Engineer, U. S. Coast and Geodetic Survey.

1. For all references see Bibliography.

Oregon. In one test run off the coast of Oregon, the Survey Ship *Guide* ran over 200 mi. directly off shore and obtained consistent positions during the entire distance; both the *Guide* and the *Pioneer* have successfully surveyed large areas with the positions of the soundings determined almost exclusively by the radio-acoustic method, the ship being as much as 75 to 80 nautical miles away from the shore station hydrophones during the progress of the work. Thus far, the method has not been used with success in the waters off the Atlantic Coast of the United States, although it has been the subject of experiments off the coasts of North Carolina and Florida.[4]

This American method differs from the British method chiefly in that the working out of position is done on board the ship, the shore station apparatus being essentially automatic so that the shore station personnel is required mainly to keep the equipment in good condition. By this means the ship's position at the instant of explosion becomes known within a very few minutes after the explosion, which is very important in survey work.

Fig. 1—Radio-Acoustic Shore Station

Space does not permit us to trace the development of the American method. The reader can refer to the Publication[3] by Commander Heck, Dr. Eckhardt, and Mr. Keiser for the details of the original apparatus and procedure. The present method has been discussed by Commander W. E. Parker,[5] Chief of the Division of Hydrography and Topography of the Coast and Geodetic Survey, and by the author.[6] It will be treated in its essentials in this paper; a more detailed description can be found in the new Special Publication of the Coast and Geodetic Survey upon the subject, which is now in press.[11]

The Shore Stations

The Survey Ship having a given water area to survey sets up two shore stations, one near each inshore corner of the area. These stations are usually 30 to 40 mi. apart and are often in wild places at a considerable distance from any towns or settlements. Since they will be used at most only a few months, the shelters are of a temporary nature, constructed or set up in one or two days by a party sent ashore from the ship. Fig. 1 shows such a station on San Clemente Island off the coast of California.

The hydrophone, sealed into a watertight, wooden case, filled with sea water, is planted on the sea bottom at a distance varying from a few hundred yards to a mile or more offshore, depending upon the topography of the bottom, the presence or absence of projecting ledges, etc. The hydrophone is a single-button microphone with a rubber case; sometimes two or more hydrophones are used, mounted in the same wooden case and usually connected in parallel. The hydrophone (or set of hydrophones) is connected to the shore station through a single-conductor cable and the sea water ground.

The wooden case into which the hydrophone is sealed may be a keg or a specially constructed box of about the size of a keg. It was introduced by the writer as the result of a study of a paper by Brillié,[7] after a series of experiments by the writer and Chief Wireless Operator A. M. Vincent, of the Survey Ship *Guide*. These experiments showed that the wooden case passes sound from the explosion without appreciable attenuation, but eliminates a great many very troublesome strays that are probably due to the mechanical action of the water, bits of sand, shells, etc., upon the hydrophone.

The cable was designed by Lieutenant Commander Thomas J. Maher, U. S. Coast and Geodetic Survey, and the author, and consists of 19-strand tinned aircraft cable ⅛ in. in diameter) insulated with a ⅛-in. belt of 40 per cent to 60 per cent rubber. This cable has great tensile strength, its insulation resistance remains high after long immersion in sea water, and the insulation is very resistant to abrasion. The high electrical resistance of this cable is not a serious disadvantage. The cable is specially manufactured for the Survey. In some localities, as on rocky beaches, single-conductor deep-sea cable is used through the breakers. Usually it is found satisfactory to run the lighter cable through ¾-in. pipe from a point inside high-water line to a point outside low water line; for protection of the cable, the pipe is fitted with a fiber or wooden bushing and a piece of rubber hose at each end.

The essentials of the shore station equipment except for batteries, are shown schematically in Fig. 2. When the sound from the distant explosion reaches the hydrophone its resistance changes and an electrical impulse passes through the input winding of the first transformer of the amplifier. This impulse, amplified, passes through the line circuit of the commercial standard telegraph relay and as a result the local circuit of that relay is momentarily closed. The closing of the local circuit of the relay has two effects; (1) the radio sending key is short-circuited by the relay contacts and a dash is broadcasted by the station with a scarcely appreciable lag behind the arrival of the sound from the explosion at the hydrophone; and (2) the automatic

key is set into operation, which is driven by clockwork, and by means of a notched wheel causes the radio transmitter to broadcast the characteristic signal of the station, which may be three long dashes, or a dot and two dashes, or whatever signal may be desired.

There is nothing of special interest connected with the amplifier. The input impedance of the first transformer is matched approximately to the impedance of the hydrophone and cable. The line circuit impedance

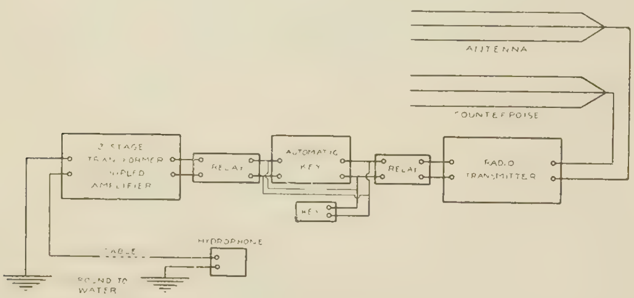

Fig. 2—Essentials of Radio-Acoustic Shore Station Apparatus—U. S. Coast and Geodetic Survey

of the relay is matched to the output impedance of the last tube of the amplifier. Usually, radiotrons UX201A are used in the first two stages, and a UX112 in the third stage. Suitable values for plate and grid potentials have been found by experiment.

The automatic key is that described by Heck, Eckhardt, and Keiser.[3] It consists of a pair of contacts connected in parallel with the radio sending key. These contacts are normally held open by a wiper resting upon the periphery of a notched wheel. This wheel is driven by a clockwork mechanism set in motion whenever the relay local circuit is closed; a device that stops the clockwork automatically when the wheel has made exactly one revolution is included.

The relay shown alongside the sending key is merely a pony telegraph relay included to insulate the sending key and the automatic key from the high plate potential of the transmitter; the transmitter is keyed in the plate circuit.

There is nothing particularly remarkable about the radio transmitter. It is simply a Hartley oscillator using two UX210 radiotron tubes in parallel and operating at 140 meters wavelength. Both stations operating in connection with a given ship must keep their transmitters adjusted to approximately the same frequency.

The Ship Installation

The essentials of the ship installation, exclusive of batteries are shown schematically in Fig. 3. The hydrophone is mounted well below the water line in a tank of water in contact with the outer plating of the ship.

The amplifier preferably has the first transformer that is connected with the hydrophone distinct from the first transformer that is connected with the output of the radio receiver, in order that the transformer input impedances may be properly matched to the impedances of the circuits into which they are connected. Usually, two or three stages of amplification are sufficient either for the incoming radio signals or for the hydrophone circuit impulses.

The chronograph drives a ¾-in. tape at the rate of about one inch per second. The drive was modified by the author and consists of a 12-volt shunt motor driven by a 12-volt storage battery of large capacity; by this arrangement satisfactory speed regulation is obtained without a governor. The pen magnet winding that is connected with the amplifier has its impedance approximately matched to the output impedance of the last tube of the amplifier.

Explosive Charges

The explosive charge is detonated by a fulminate blasting cap into which a short length of waterproof fuse is fitted. If the ship is within 15 or 20 mi. of each of the two stations, one of these blasting caps will usually send sound energy of sufficient amplitude to the hydrophones at both station to actuate the station apparatus. Beyond the range of a blasting cap, a friction top, pint-size, tin can filled with TNT into which the blasting cap is imbedded is usually sufficient. For the greatest distances, a bomb designed by the author is used. This bomb consists of a hollow cast iron spheres of 5-in. inside diameter and ½-in. wall thickness, filled with TNT; the blasting cap and fuse (as well as the TNT) are introduced through a small opening; the blasting cap is imbedded in the TNT at the center of the sphere. In these cast iron bombs, as

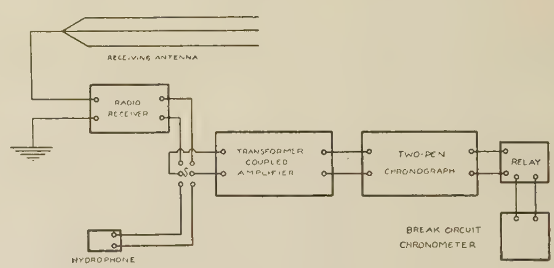

Fig. 3—Essentials of Radio-Acoustic Ship Apparatus—U. S. Coast and Geodetic Survey

well as in the tin can bombs, the fuse opening is sealed with soft pitch or some similar material after the fuse is in place.

Operation of the System

When a position is wanted, the switch *S*, (Fig. 3) is thrown to the hydrophone, the chronograph is started, the pens are seen to be functioning with the time pen making the second marks, and a bomb is ignited (by touching the end of the fuse to a hot wire) and thrown overboard. The ship need not modify either her course or speed for this procedure. The instant of explosion is recorded on the chronograph by means of the ship's hydrophone, the amplifier, and the amplifier pen

magnet. The switch S, (Fig. 3) is then thrown to the ship's radio receiver.

The sound energy flows out from the explosion and, after intervals, reaches the hydrophones at the two stations. When this sound reaches the hydrophone at a given station, that station, with scarcely appreciable lag, broadcasts a radio dash, identified immediately afterward by the characteristic signal of the station. Dash and signal are received by the ship and recorded on the chronograph tape. The time of travel of the radio dash from station to ship is negligible. Instrumental lags can be determined at the beginning of the season and then checked from time to time.

From the chronograph tape, the time of travel of sound energy from the explosion to the hydrophone at each station can be read off quickly to within one or two one-hundredths of a second. The positions of the station hydrophones have been located accurately and plotted upon the survey sheet when the hydrophones were planted.

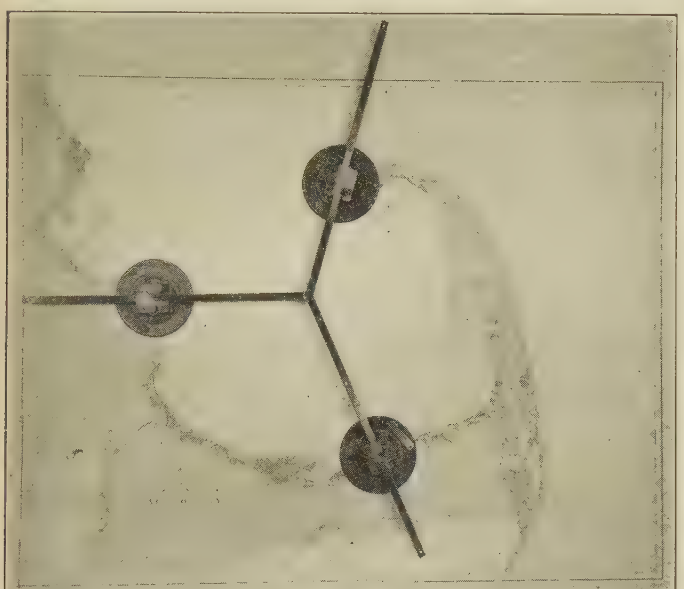

FIG. 4—PARKHURST—SERVICE RADIO-ACOUSTIC PLOTTER

SPEED OF SOUND IN SEA WATER

Since the distance from the explosion to the hydrophone at each station is required, in addition to the time of travel of sound energy to each station the speed of sound in sea water must be known. This speed is a function of the mean (from surface to bottom and over the range) temperature, pressure, and salinity of the water. From studies made within the past few years the speed of sound in sea water is quite well known under all conditions of temperature, pressure, and salinity likely to be encountered.[4, 8, 9] Also, the temperature and salinity conditions are determined during the season in order that correct sound speeds may be known for echo soundings. Hence, it may be assumed that the correct speed of sound for computing radio-acoustic ranges will be available.

PLOTTING THE POSITIONS

Since the positions of the station hydrophones are known and have been plotted upon the survey sheet, and the distances from the explosion to each hydrophone have been determined by the radio acoustic method, the problem is to find (upon the survey sheet) the vertex of a triangle when the base and the lengths of the other two sides are known. This problem would be easy of solution were it not for the distortion of the survey sheet and the necessity for economy of time. In the plotting of the final "smooth sheet," corrections must be made for distortion, and speed is not so essential; in the plotting of the preliminary work sheet or "boat sheet," distortion may usually be disregarded and speed is quite important.

For plotting on the boat sheet where distortion of the sheet may be disregarded, the plotting device designed by Douglas L. Parkhurst, Chief of Division of Instruments of the Coast Geodetic Survey, and the author, can be used to advantage. This plotting device is shown in Fig. 4, and consists of a pair of arms pivoted at a pricking device; with zero at the pivot, graduations are marked on the arms which represent the distances (on the scale of the hydrographic sheet) that sound will travel in the number of seconds represented by the graduation marks; of course, a mean value of the speed of sound in sea water must be used in laying out the graduations on these arms. An index head is tacked to the chart table through the survey sheet over the plotted position of each hydrophone. The arms slide in grooves on these index heads. Suppose then, that it is found that sound travels from the ship to hydrophone A in 44.82 seconds, and to hydrophone B in 39.19 seconds. The arm in the index head that is over the plotted position of A is moved in or out until graduation 44 is opposite 0.82 on the index head, and then clamped; likewise 39.19 is set up on the arm that slides in the index head at B. The pricker will then be over the position of the ship on the sheet, and the position can be pricked.

Three arms and three index heads are provided, but usually only two are used because there are generally but two stations.

ACCURACY OF THE METHOD

The accuracy of the method is limited by the accuracy with which the speed of sound is known and by the angle at which the two distance lines intersect. If the physical conditions of the water are fairly well known, the speed, and therefore the two distances, will have an uncertainty not greater than 0.5 of 1 per cent, probably no greater than 0.3 of 1 per cent. That is to say, if the ship is about 50 mi. from the two hydrophones, she can determine her position from either with an uncertainty of the order of 300 meters. Then, of course, the accuracy of her position, determined from the two distances, will depend upon the angle of inter-

section of the two arcs about the respective hydrophones as centers.

Captain L. Tonta, Director of the International Hydrographic Bureau, has proposed[10] a rather brief method of computation of radio-acoustic positions that may prove of advantage for final plotting on the smooth sheets. This method eliminates error of position due to a small error in the value assumed for the speed of sound. The reader is referred to Captain Tonta's original paper for the details of this method.

In conclusion, the author wishes to express his appreciation to those of his superior officers and associates in the Coast and Geodetic Survey who have helped him in the preparation of this paper, and to C. L. Terrel, of the class of 1928 at the Ohio State University, who inked and lettered the diagrams.

Bibliography

1. Joly, in *Phil. Mag.*, 36, June, 1918, and *Proc. Roy. Soc.*, A, 94, August, 1918.

2. A. B. Wood and H. E. Browne: "A Radio Acoustic Method of Locating Positions at Sea: Application to Navigation and to Hydrographical Survey." *Proc. Phys. Soc.* of London, April 15, 1923, Vol. 35, Part 3, p. 185.

3. N. H. Heck, E. A. Eckhardt, and M. Keiser: "Radio-Acoustic Method of Position Finding in Hydrographic Surveys." *U. S. Coast and Geodetic Survey Special Publication No. 107*, Washington, Government Printing Office, 1924.

4. Jerry H. Service: "Transmission of Sound through Sea Water." *Doctorate Dissertation*, Ohio State University, 1928.

5. W. E. Parker: "Radio-Acoustic Ranging." *Engineering News Record*, February 7, 1927.

6. Jerry H. Service: "Recent Results with Radio-Acoustic Position Finding in Hydrography." Paper read before the Philosophical Society of Washington, January 23, 1926. Abstract in *Jour. Wash. Acad. Science*, Vol. 16, April 4, 1926, p. 198.

7. H. Brillié: Étude des Ondes Acoustiques. La propogation des ondes vibratoires et l'écoute-sous-marine." *Génie Civil*, Vol. 75, pp. 171, 194 and 218, August 23rd and 30th, September 6th, 1919.

8. "Tables of the Velocity of Sound in Pure Water and Sea Water for use in Echo-Sounding and Sound-Ranging." Hydrographic Department, Admiralty, London, 1927.

9. N. H. Heck and Jerry H. Service: "Velocity of Sound in Sea Water." *U. S. Coast and Geodetic Survey Special Publication No. 108*, Washington, Government Printing Office, 1924.

10. L. Tonta: "Submarine Phototelemetry." A New Radio-Acoustic Position Line." *The Hydrographic Review*, Vol. IV, No. 2, Monaco, November, 1927.

11. "Radio-Acoustic Position Finding." *U. S. Coast and Geodetic Survey Special Publication No. 146*, Washington, Government Printing Office, 1928.

An Experimental Determination of Electrostatic Field Near a Plate With a Projecting Rod

BY W. W. MITKEWICH

Non-member

It is a well-known fact that the electrical field in any hollow or cavity in a solid conductor is either zero or very nearly approaches zero. This follows directly from the inverse-square law.

Referring to Fig. 1, consider a plane conductor *b* provided with a vertical wall *a*, also of conducting material; if such a system were charged, we should find that the field strength rapidly falls off as we approach the corner junction.

For example, in a model with linear dimensions of about 30 cm., this field is experimentally found to be practically zero at a point located 6 mm. from the corner. From such experiments we generally obtain an idea that the vertical wall *a* annuls the electric field due to the plane *b*, since this is a case of a depression in a charged conductor. We can readily apply the inverse-square law reasoning in deducing this field-elimination effect.

However, one would hardly suspect a thin metallic rod positioned in the center of a charged surface, such as shown by Fig. 2, to be practically equivalent to the very much larger plane in annulling the electric field about itself. Having found such a condition experimentally, we can readily think of an explanation based on the inverse-square law, since the direction of the field at any point in the space immediately surrounding the rod *c* is in a plane passing through the rod.

Referring to Fig. 3, a stand *a* holds a metallic plate *c* which is insulated from *a* by a piece of insulating material *b*. A rod *d*, 1.65 mm. in diameter, protrudes through a hole in the plate located 19.1 cm. from either the upper or right edge of the plate. A tube *h*, placed behind the plate, holds the rod *d* in a horizontal position, perpendicular to the plate *c*. A scale *g* shows the horizontal distance to the right from the rod on the surface of the plate.

A gold leaf *e* is held on the scale *g* by the metallic flat rod *f*; a spring *k* holds the rod *f* in position. A small scale *i* fixed on the rod *f*, at some distance from the gold leaf, indicates the deflection of the gold leaf *e*.

This apparatus is charged by means of an electrophorus plate held in one's hand. The insulation *b* is made of hard rubber.

Curves are obtained showing the variations in the deflection *q* of the gold leaf, with changes in the height of the rod *h* and the distance of the gold leaf from the rod *d*.

A similar experiment is repeated with a 16.8-cm. by 25.4-cm. metal plate used in place of the rod placed perpendicularly to the plate *c*, and having its surface in a vertical plane.

On placing the gold leaf at a distance of 1.25 cm. from the rod, on reducing the height of the rod to zero and on charging the system, the gold leaf is found to deflect to approximately a horizontal position. But

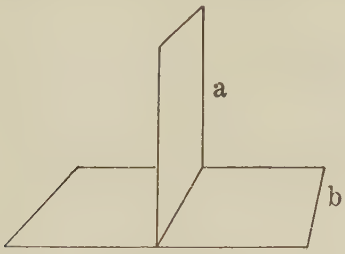

Fig. 1

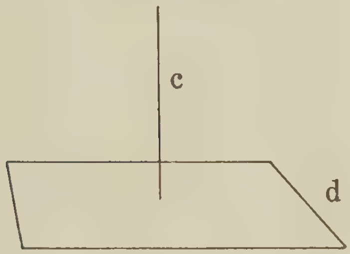

Fig. 2

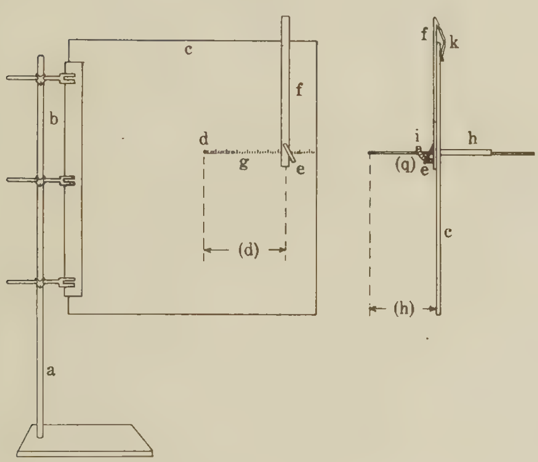

Fig. 3

as soon as the rod is brought to the height of 5 cm. the gold leaf falls back to the close proximity of the plate *c*, and as soon as the rod is again reduced to zero height the leaf again deflects to the position which is almost perpendicular to the plate *c*.

It must be remembered that the most striking appearance of this phenomenon follows from the condition of having the rod only 1.65 mm. in diameter while the gold leaf is 1.8 cm. by 0.5 cm. in measurements and contains an appreciable area as compared with the projection of the wire rod.

The curves represented by Fig. 4 show the gold leaf deflection q plotted against the distance of the gold leaf from the center d. The upper curve is taken with the plate *c* empty, that is with the height of the rod reduced to zero. The slight curvature at the points farthest from the center is due to the edge effect of the static field, but in general the field is almost uniform throughout the sheet *c*.

The lower curve is taken with the perpendicular and vertically positioned plate in the center. The plate measures 25.4 cm. vertically and stands out 16.8 cm. horizontally. The results show that the electroscope does not deflect at all next to the plate and the deflection

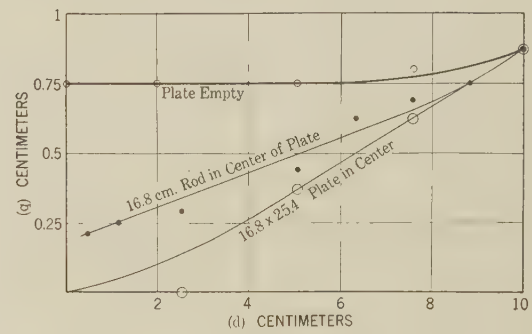

Fig. 4

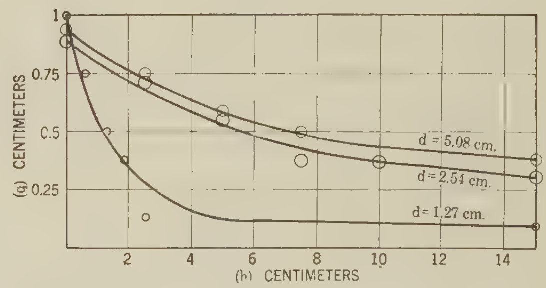

Fig. 5

gradually becomes apparent as we move the gold leaf further away from the plate-wall along the plate *c*.

The middle curve shows the identical experiment repeated with the rod of 1.65 mm. diameter and height 16.8 cm. (horizontal measurement).

Fig. 5 shows the variations in the deflection q with changes in the height of the rod h for different fixed positions of the gold leaf.

MINERALS CONSERVED BY U. S. GEOLOGICAL SURVEY

Under the supervision of the mining engineers of the Geological Survey it is estimated that minerals valued at $150,000,000 will have been recovered from the earth in the public land states of the west during the current year. The returns in rental and royalty will amount to nearly $20,000,000 according to a statement recently made public by the Department of the Interior in reporting upon this work.

Field administrative work of the department has been pushed during the summer months and this will mean additional millions to the public. The lands covered are scattered through all of the public land states and are dealt with through 20 stations where petroleum and mining engineers of the Geological Survey are located to supervise the development. Conservation of the minerals and other natural resources of the country is one of the prime objectives of this work.

Abridgment of

Transmission and Distribution

ANNUAL REPORT OF THE COMMITTEE ON POWER TRANSMISSION AND DISTRIBUTION*

To the Board of Directors:

In addition to conducting its usual activities during the current year, this Committee has endeavored to establish a closer contact with those committees of other organizations whose interests lie in a large measure within the field with which it is concerned. It was felt that such cooperation would be mutually beneficial and through the medium of the Institute publications would result in the presentation of some material of general interest which would otherwise receive only limited circulation. It is believed that the present report has benefited very materially by this policy.

After considering some criticisms of the definitions contained in the "Wires and Cables" section of the A. I. E. E. Standards, the Committee deemed it advisable to have these definitions revised. A suggested revision has been prepared and placed in the hands of the Standards Committee.

Overhead Transmission Lines

Lightning on Transmission Lines. The protection of overhead transmission lines from interruptions due to lightning flashovers remains a problem of outstanding importance and in order to make more quickly available records of operating data on the protective value of ground wires, fused grading shields, and wood or combination steel and wood transmission line structures with regard to reducing lightning flashovers, a subcommittee undertook to collect as much information in this field as possible. For all data so obtained, reference should be made to the complete report.

Better performance resulting from adding a ground wire to an all-wood line seems clearly indicated from the comparison of 1926 and 1927 experience with that of 1925 of the data reported by companies No. 1 and No. 5. Similar improvements in reliability are indicated when ground wires have been added to steel tower lines.

Western companies report bird troubles as being more severe than those due to lightning, and wood construction very advantageous in this respect as shown by the data submitted by Company No. 6. However, there seems to be a crystallization of sentiment in the West in favor of steel towers with suitable bird guards, because of the very considerable trouble experienced with destructive fires due to leakage currents with wood construction, especially at certain seasons of the year.

For lower voltage lines, 22- to 66-kv., there is an increasing tendency to try to improve designs of wood pole lines with a view to reducing lightning troubles by the use of wood pins, arms and braces, and by increasing the amount of insulation inserted in the guy wires.

Company No. 1, reporting on the value of fused grading shields, shows a 50 per cent reduction in outages on two circuits, on one tower line so equipped compared with two circuits on a parallel tower line protected by ground wire only. It also states that this type of protection functioned correctly two out of every three times; *i. e.*, cleared the follow-up dynamic arc before the breakers opened and thus avoided dumping the load. The record as to the performance of the individual fuses was even better—77 per cent correct operation, *i. e.*, 77 per cent cleared properly—and were not the cause of a line interruption.

Another company desirous of trying out this type of protection on 132-kv. circuits reports that it has not as yet been able to find a fuse for that voltage which, after testing, it felt was safe to install for this purpose.

Theory of Lightning and Ground Wires. The results of the work of a number of investigators during the past year have altered to some extent the conceptions regarding the nature of the lightning stroke and the manner in which it affects transmission lines.

The theoretical considerations involved are discussed in some detail in the complete report. The protective effect of the ground wire is discussed also in the light of the latest concepts and figures are given indicating the reduction in induced potentials to be expected from various arrangements of the ground wires.

The protection against flashover afforded by the use of ground wires is much greater than the percentage reduction in voltages. If the number of lightning surges of any given potential is plotted against the voltages, the resulting curve resembles a rectangular hyperbola. From this it is seen that of those lightning strokes, both direct and induced, which cause flashover, those that are not more than twice the flashover voltage of the insulators are much more numerous than those which are many times that value. Therefore, if each surge is reduced to one-half its voltage, the num-

*POWER TRANSMISSION AND DISTRIBUTION:
Philip Torchio, Chairman,
H. C. Forbes, Secretary,

R. E. Argersinger	C. L. Fortescue,	P. Sporn,
R. W. Atkinson,	C. D. Gibbs,	E. C. Stone,
P. H. Chase,	C. D. Gray,	R. H. Tapscott,
W. S. Clark,	K. A. Hawley,	P. H. Thomas,
R. N. Conwell,	J. P. Jollyman,	W. K. Vanderpoel,
M. T. Crawford,	A. H. Kehoe,	Theodore Varney,
W. A. Del Mar,	W. B. Kirke,	H. L. Wallau,
H. H. Dewey,	A. H. Lawton,	H. S. Warren,
L. L. Elden,	D. W. Roper,	F. R. Weller,
F. M. Farmer,	A. E. Silver,	R. J. C. Wood.
	M. L. Sindeband,	

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

ber of flashovers is reduced by a much larger factor. Operating experience of the past few years seems to indicate that on the high-voltage lines flashovers are practically eliminated by ground wires which give a 50 per cent reduction.

Topography in Relation to Lightning Flashovers. An investigation of the flashovers which have occurred on the Cahokia-Crystal City transmission line, which was put in service May 11, 1925, indicated a close relationship between the topography of the surrounding territory and the flashovers on the line.

From this study it appears that short sections of ground wire placed over the portions of the line most subject to flashovers should be almost as effective from the standpoint of protection as a ground wire over the entire length. Eight miles of ground wire divided into four sections would include those parts of the line upon which 70 per cent of the flashovers have occurred.

Results of Klydonograph Investigation. The preliminary results of an extensive klydonograph layout which was planned and placed in operation during 1927 in connection with studies of the Subcommittee on Lightning showed switching surges up to 5.2 times normal to ground, checking quite closely previous data on this phase of the problem: All switching surges were either highly damped or unidirectional with small magnitude. These surges do not appear to be at all troublesome to line or apparatus, at least in the line investigated. Lightning voltages were recorded up to 4.8 times normal and in one case where the line tripped, over 19 times normal was found. Of the surges recorded 57 per cent were positive, 18 per cent were negative, and 25 per cent oscillatory.

Lightning arrester discharges were found as high as 2620 amperes in the neutral leg of a four-leg oxide film arrester on a 132-kv. system. Another case of 1260 amperes was observed. Both currents were negative initially, the latter being highly damped.

Voltages on the protective ground wire were observed as high as 20,000 volts in one case, and many voltages were recorded in the order of 2000 to 3000 volts.

The field investigation is being continued in 1928 and it is expected that after the data for 1928 have been collected and assimilated a fairly complete report can be presented.

Underground Cables

General Review. The outstanding feature of underground transmission during the year is the placing in service in the summer of 1927 of 18 mi. of 132-kv. lines in Chicago and New York. These installations were described before the Institute at the Chicago Regional Meeting in November 1927. There have been no electrical failures on these installations, and the only troubles have been minor oil leaks in joints and other appurtenances and a few leaks in cable sheaths. In all cases of leaks the repair work was deferred until the line could be taken out of service without inconvenience to the operating company.

All of the available evidence indicates that on the whole there has been a distinct improvement in the quality of high-voltage cable during the past few years. Statistics on more than 5,000,000 ft. of such cable purchased under rigid specifications by a group of central station companies show that only 3.22 per cent of the cable submitted during 1927 was below the standards prescribed by the specifications,—the lowest of continually decreasing percentages during the past five years. There has been a steady increase in dielectric strength of cable during the past few years. Dielectric losses and power factor are at about a minimum,—the average power factor for cable with a wide range of voltage ratings and sizes being about 0.6 per cent at room temperature and operating voltage.

Another outstanding feature has been the marked decrease in the effect of bending on the dielectric strength of paper-insulated lead-covered cables. For the past two or more years cable could be subjected to a very severe bending manipulation without any appreciable effect on the dielectric strength.

Effectiveness of Specifications and Cable Performance. The effectiveness of specifications and the accompanying inspection and tests in guaranteeing satisfactory service of cable are often questioned and few data exist from which definite conclusions may be drawn.

The importance of this question and the still greater importance to the operating engineer of thoroughly reliable records of cable performance have been recognized and all of the important data in connection with all failures of cable in service on a number of the larger systems are now being systematically collected. It has already been found that a very considerable percentage of the sections of cable which failed in service without external cause had some abnormal feature of more or less significance in the original inspection record.

Quality Rating. It is generally recognized that all items of inspection and test are not of equal value, and that no characteristic determines the quality of a given piece of cable. On the other hand it is probably true that no two engineers will agree as to just which characteristics do determine cable quality. Nevertheless, it is appreciated that a method of weighing characteristics, assigning grades on a scale of test performance for each characteristic and thereby obtaining a single figure of merit for a given lot of cable, would furnish an engineer with a useful means of evaluating that cable. Such a procedure of quality rating has been set up and is now being applied in the cooperative work referred to above. Such a procedure, even though strictly empirical, if it proves to coordinate with service records, will be of great value to the industry.

Losses in Armored Single-Conductor Cable. The calculation of potential drop and energy loss in single-conductor steel armored cables used for three-phase circuits is not susceptible of accurate predetermination with the information now available.

The variety of iron armored single-conductor cables

tested and the data obtained have not been sufficient to permit establishing a generally applicable calculating procedure for circulating currents and losses. While the data available cover sufficiently well for practical use the loss calculations for the few designs considered, iron armored cables of radically different design would probably require additional empirical data to be derived from tests, as a basis for the calculations. If the proper additional tests were made for a few other types of armored designs, a more general calculating procedure could probably be established.

A paper[1] is under preparation reviewing the knowledge at hand, and reporting the results of recent tests and analysis as a further step of progress toward a more general understanding of the problem.

A-C. Electrolysis of Lead Cable Sheaths. The use of single-conductor cables in separate ducts for three-phase circuits of high voltage has led to the adoption of various methods for the reduction of induced currents in the sheaths. These schemes entail a-c. potentials from the sheaths to ground of varying magnitudes and the question of whether electrolytic corrosion of the cable sheaths is likely to result from this practise is of considerable importance.

Further investigations of this subject are under way and will doubtless add much valuable information to our present supply, which is none too complete.

It may also be appropriate to mention here that some trouble has been experienced with lead sheath corrosion due to the formation of a red lead oxide. This subject was discussed at a special meeting during the April Regional Meeting, which was held in Baltimore, and as a result of investigations now under way, more detailed knowledge will probably soon be available.

Power Limits of Systems

Further progress is reported in the development of methods for predetermining power limits of systems and of criteria for system stability. From this standpoint, important progress has also been made in synchronous machine theory.

Last year's report indicated the extent to which high-speed or quick response excitation had been adopted as a means of preserving synchronism in a system during short circuits. The installations made to date are the Farmersville substation of the Southern California Edison Company, the Gatineau Falls Development of the International Paper Company, and the Conowingo Development of the Susquehanna Power Company. The experience obtained to date with these installations has been insufficient to draw any definite conclusions regarding their effectiveness in maintaining stability. Without such operating experience, the committee has no further statement to make except to repeat the opinion generally held that there is a number of cases where quick response excitation may be advantageous. It is not a panacea for system troubles.

1. By O. R. Schurig, H. P. Kuehni, and F. H. Buller.

Further progress is reported in factory tests of power transmission, using voltage regulating devices, substantiating previous tests demonstrating the possibility of stable operation under a condition of dynamic or artificial stability, that is, at values of power considerably above the limit with fixed excitation. It is thus a promising development as regards increasing the maximum output of synchronous machines. It is expected that even if it is not necessary at the present time to transmit regularly values of power above the steady-state limit, there may be occasions when certain branches of a system may be momentarily loaded beyond the steady-state limit, due to switching operation, sudden load shifts, etc., and the devices referred to should prove beneficial under such conditions.

There is an urgent need for further field data. These data should take two forms:

a. Further tests on systems for which calculations have been made, as a check on such calculations.

b. Data secured during transients encountered in normal operation, by means of special recording devices, such as the automatic oscillograph and the high-speed recorder. Preferably these data should also be obtained on systems for which calculations have been made.

It is felt that in the problem of maintaining synchronism between all machines connected to a system during short circuits, very considerable benefit will be obtained by reducing as far as possible the magnitude and duration of the disturbance caused by a short circuit. It is not generally practicable to reduce the short-circuit current by the introduction of series impedance in the path of load currents as this decreases the power limits directly. Since, however, most short circuits occur from line to neutral, considerable benefit may be expected from making use of means which limit the value of line to neutral short-circuit current without increasing the impedance of the system to normal load current.

Bibliography

For references to many important papers and articles dealing with the subjects which have been discussed the complete report should be consulted.

Acknowledgment

The material in this report has been obtained from a multiplicity of sources and includes contributions made through the courtesy of committees of other organizations as well as those of subcommittees and individual members of this committee. Without making a detailed acknowledgment, the chairman wishes to take this opportunity of expressing to the contributors as a group the appreciation of this committee as well as his own personal thanks for the generous manner in which they have all given so unstintedly of their time and information.

Philip Torchio, *Chairman.*

Abridgment of

Production and Application of Light

ANNUAL REPORT OF COMMITTEE ON PRODUCTION AND APPLICATION OF LIGHT*

To the Board of Directors:

This Report was compiled by the members of the Committee, assisted by about 35 experts who contributed material or passed upon statements embodied in the report, which will be printed in full in the Institute's TRANSACTIONS. Following is a review of its general features.

PRODUCTION OF LIGHT

Most developments during the past year in the production of light have taken the form of refinements of design and adaptations of existing types of illuminants rather than of radically new methods or principles of light production.

Incandescent Filament Lamps

Small Multiple Lamps. The report describes the new and smaller 10-watt multiple lamps equipped with

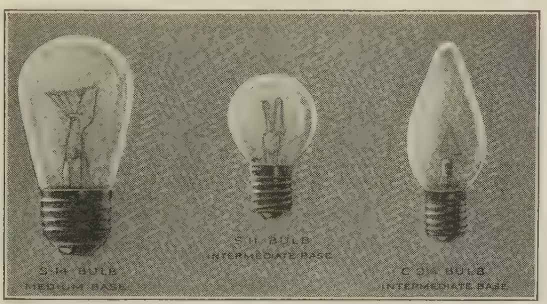

FIG. 1—10-WATT MULTIPLE LAMPS

new "intermediate" bases recently produced. These are especially suitable for decorative lighting, being available in a variety of coated bulbs. In the type designed more particularly for indoor use, an average life of 600 hr. is adopted, while for those in the round bulb form, more suitable for outdoor use, a 1500-hr. life has been fixed. The latter is expectd to find wide use in electric signs and in outdoor decoration. A complete line of intermediate base sockets, and adaptors, is available for use with these new small lamps.

Very Large Lamps. Lamps up to the 10-kw. size which have been produced successfully point the way toward still larger lamps for special purposes when and if needed.

Projection Lamps. The "coiled-coil" filament provides for projection purposes a smaller light source, making possible increased intensity and uniformity of screen illumination. A pre-focusing base makes possible more accurate positioning of the filament.

Street Railway Lamps. The 36-watt vacuum lamps for use, five in series on circuits of 525 to 650 volts, were made available during the past year. Gas-filled lamps for operation approximately 20 in series at 30 volts per lamp were another new development in this field. The latter lamps have incorporated a special device for reestablishing the circuit in case of filament failure.

Short-Circuiting Device for Street Series Lamps. In a new form of street series lamps, lead-in wires have been brought into close proximity. In case of filament failure, if the arc travels along the lead wires, a short circuit is formed at this point affording protection to the lamp socket.

Searchlights

Since the war, the trend of development of military searchlight design has been toward greater beam candlepower, lighter weight, greater mobility, and improved methods of control. There were two important developments in 1927. One of these was the incorporation in the searchlight unit of a comparator system which makes it possible for the searchlight to be guided from a distance by accurate data transmitted electrically from a sound-locator station to the searchlight station. Thus, in anti-aircraft defense, the pointing of the searchlight at the target is greatly facilitated.

The other development was the successful production of a 60-in. mobile searchlight unit employing a 250-ampere high-intensity arc operated by a 25-kw. generating unit, and developing 1,385,000,000 maximum beam candlepower.

In order to facilitate signaling, searchlights of the smaller sizes in the Navy are being adapted to the employment of the incandescent lamp. Similar signaling searchlights using 1000-watt projection lamps have unique advantages in the submarine service, in that the pressure on the projection drum may be equalized by allowing water to enter the unit.

Gaseous Conductor Lamps

Sign Types. Concerning neon tube signs, it is noted that the efficiency of light production of the orange-red neon tube sign is relatively high and the guaranteed service life is long. Such signs require a relatively high voltage and are characterized by a power factor usually below 50 per cent.

Hot Cathode Lamps. The latest development in

---

*COMMITTEE ON PRODUCTION AND APPLICATION OF LIGHT:

Preston S. Millar, Chairman,

W. T. Blackwell,	G. C. Hall,	F. H. Murphy,
J. M. Bryant,	L. A. Hawkins,	F. A. Rogers,
J. R. Cravath,	H. H. Higbie,	B. E. Shackelford,
W. T. Dempsey,	C. L. Kinsloe,	C. J. Stahl,
William Esty,	A. S. McAllister,	G. H. Stickney.
	George S. Merrill,	

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

gaseous conductor lamps recently announced in two papers before the Institute is reviewed. This lamp, similar in form to the well-known mercury vapor lamp, utilizes neon gas and, by means of an electrically-heated cathode which reduces the voltage drop at the electrode from about 250 to about 30 volts, makes operation possible on a 115-volt circuit. Through avoidance of electrode disintegration, a comparatively large current

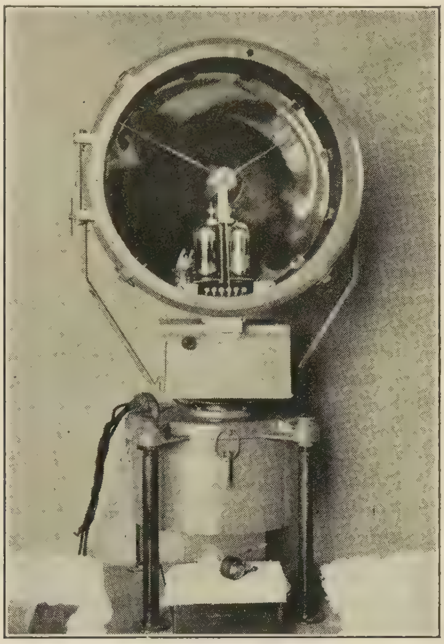

Fig. 2—Neon Induction Beacon

may be passed with resultant high brilliancy and candlepower.

Application of Light

Interior Illumination

Industrial Lighting. The Report emphasizes the large place which lighting holds in industrial power,

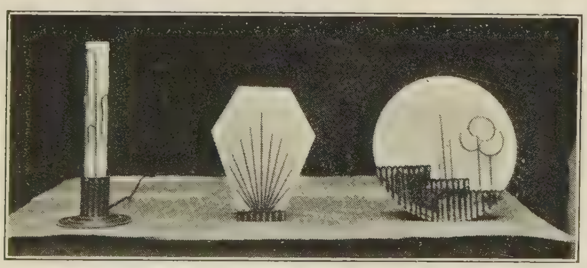

Fig. 3—Luminaires in the Modernistic Spirit

citing a survey of a considerable number of industrial plants in which it was found that electricity consumed for lighting approximated, on the average, that for power purposes.

Commercial Lighting. A continued advance to higher intensity levels in store and show-window lighting is featured by innovations in the way of modernistic lighting equipment and by the more general use of color-matching units.

Residence Lighting. Lighting equipment in the modernistic vogue is making its appearance in residence types which, whatever may be said as to their artistic success, as a class are characterized by better shielding of lamps than in many fixtures of older types.

Lighted ornaments are beginning to make their appearance in both the imported and domestic fields.

In this connection, the Report notes the importance of arriving at most constructive solutions of the several problems of residence wiring which now confront the electric lighting industry.

Theatrical Lighting. In this field, the utilization of electric light is making rapid strides. Applications of higher intensity illumination under better control are bringing improved results.

Exterior Illumination

Street Lighting. The Report notes a tendency toward higher amperage circuits—20 amperes for supply of 20 ampere lamps in place of transformers supplying such lamps from circuits of lower amperage. Developments in remote-control of street lighting circuits are reviewed.

The relation between street lighting and motor

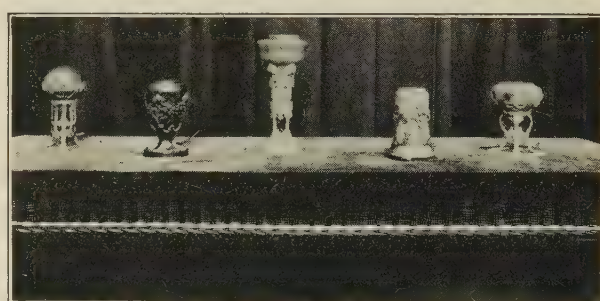

Fig. 4—Lighted Ornaments for Household Decoration

vehicle lighting is discussed with emphasis upon the importance of providing adequate street lighting in urban districts and important highways in order to permit automobile driving without powerful headlamps on such streets. A joint resolution adopted by the Committee on Street Lighting and the Committee on Motor Vehicle Lighting, (both of the I. E. S.), is quoted in favor of the practicability of such lighting on traffic thoroughfares.

Automobile Headlighting. The Report reviews developments in specifications for automobile headlamps to cover the advantageous use of double-filament lamps providing depressed beams for use when passing other automobiles.

Traffic Signal Lighting. Recent developments in attempts to standardize traffic signal lighting are reviewed with indications that material will shortly become available which will make possible much needed progress in this direction.

Sign Lighting. The rapid advance in the use of electricity for sign lighting of a great variety of types, with both incandescent and neon tube lamps, is reviewed with mention of sky projection. Animated

bulletin board types of signs and porcelain enameled steel letters for signs are also mentioned. The advent of chromium plated sign letters for outdoor use is announced.

Lighting of Building Exteriors. The rapid increase in the application of color in the lighting of building exteriors is noted with illustrations of some outstanding recent installations and with review of tendencies in the practise of lighting building exteriors.

Other Special Types of Lighting

Brief review of developments in the lighting of railroad yards and railroad signaling is offered. Floodlighting is coming to be the recognized practise for lighting railroad yards and light signals are replacing semaphores for railroad signaling. The Report reviews the application of electric light to lighthouse service. In this application, however, electric lighting is handicapped because the optical equipments of many lighthouses were designed for relatively large area sources.

Lighting for Aviation. Stating that 5800 mi. of air

Fig. 5—Sky Projector

route are now provided with night flying facilities, the Report describes typical installations which include beacon lights 10 mi. apart, or closer where required, and lighted intermediate landing fields about 30 mi. apart.

The beacom lights are erected on 50- or 75-ft. steel towers at the bases of which are chrome yellow arrows 56 ft. long to indicate the line of flight. The number of the beacon is painted in black on the arrow for daytime identification. The beacon light consists of three units, a revolving searchlight synchronized with two flashing red course lights. The revolving beacon has a 24-in. parabolic mirror and a 1000-watt, 110-volt T20 incandescent lamp, designed to yield an average life of 500 hr. The beacon develops a beam intensity of from two and three million candlepower. Its axis is elevated two degrees above the horizontal and it is rotated about a vertical shaft by a motor and worm gearing at a rate of six rev. per min. Auxiliary contactors on the vertical shaft interrupt the current to the course lights according to a code by which the pilot identifies the beacon.

Each course light consists of a 500-watt, G40 incandescent lamp in a 14-in. parabolic reflector with a red or amber 30-deg. spreadlight cover glass. The electric circuits are controlled by astronomical clocks which

Fig. 6—Floodlighting of Edison Building, Philadelphia, Pa.

turn the lights on at sunset and off at sunrise. Where commercial electric service is not available, two-kw. full automatic gasoline engine generators are installed in duplicate. In the event of engine failure a relay places the stand-by generating unit in operation.

Intermediate landing fields are marked with a revolving beacon, a boundary lighting system, obstruction lights, and an internally lighted wind cone. The fields usually have two landing strips at right angles to each other, each about 500 ft. wide and 2000 ft. long.

Fig. 7—Floodlighting from Ornamental Street Lighting Posts

The boundaries of the landing strips are marked by 15-watt or larger multiple lamps in clear white refractor globes spaced about 300 ft. apart or by series lamps of equivalent candlepower. Green range lights mark the favorable approaches and 25-watt or larger multiple lamps in red globes are mounted on all neighboring obstructions.

To meet the requirements for terminal fields, 425 airports have been established or are under construction by municipalities in the United States. The Depart-

ment of Commerce has established an airport section to cooperate with city officials for proper selection and development of airports. Extensive tests were made during the past year in the landing of aircraft at night under varying conditions and floodlighting systems.

The outstanding developments in airport lighting during the year were a new system of grouping of incandescent floodlight units on one or more sides of the landing field, an intermediate size dioptric floodlight unit using the five-kw. incandescent lamp, illuminated field markers and wind-direction gages and a 55-ampere high-intensity arc floodlight unit with two degrees vertical and various degrees of horizontal spread of beam. Neon tube beacons and boundary lights have been advanced in development during the year and it is understood that in Great Britain and Germany they are employed very generally in lighting for aviation. A practical method has been demonstrated for automatically controlling landing field floodlights through switches actuated by the noise of the airplane or by a whistle of distinctive tone mounted on the plane.

Lighting for Night Recreation. To extend the uses of recreational areas into the dark hours, artificial lighting is being used more and more. Lighting installations for night tennis, football, races, bowling on the green, hockey, horseshoe pitching (quoits) and indoor baseball, are numerous and assure the practicability of night sports. Extensive investigations at Lynn, Mass.

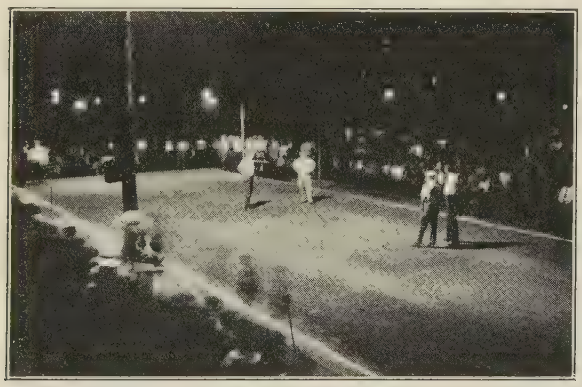

Fig. 8—Illuminated Court for Quoit Matches

indicate that in no very distant future the great national game of baseball may be played at night under artificial illumination.

During the past year, special progress has been made in the application of artificial light to swimming pools. In addition to levels of illumination of the order of 5 to 10 foot-candles over the entire pool area to insure safety and comfort, it has been found desirable and feasible to provide, in the deeper parts, under-water illumination from units below the surface. Equipment which can be installed quite economically has recently been made available for this service.

Christmas Lighting. This year more attention has been paid to decorative Christmas lighting than ever before. Over 50 communities conducted contests during the holiday season in the decorative lighting of residences, all of which were successful to a greater or lesser degree. Greater interest, as manifested by the larger number of entries, has come where the contest has been divided into several classes or districts so that moderate homes were not expected to compete on an equal basis with wealthy homes.

Lighting for Agriculture. The Report reviews the present status of knowledge of the application of light for purposes of agriculture, indicating need for much further experimental work before this application can be considered to be thoroughly understood. Some effects

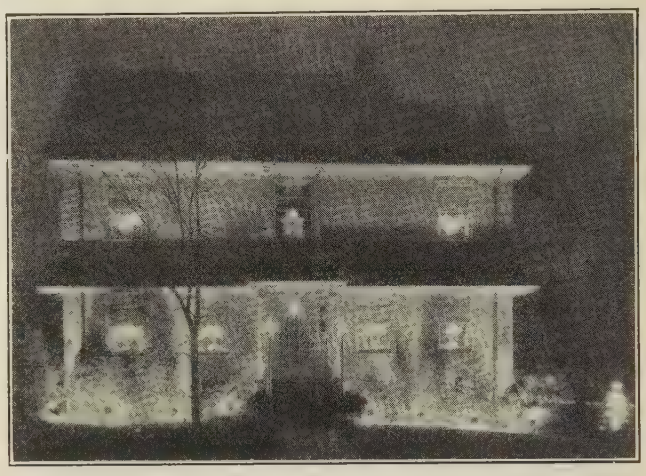

Fig. 9—Decorative Lighting of House for Holidays

which have been observed on plant growth, insect destruction, and stimulation of poultry-egg production are indicated.

Ultra Violet Radiation. The application of ultra violet radiation for health and industrial purposes is discussed briefly with indication of the need for experimental work and a probable large utility for such applications in the future.

Photometry. The Report concludes with a review of recent developments in the application of the photoelectric cell and in methods for photometry of projectors.

COST OF OIL PRODUCTION REDUCED

In order to enable it to meet economic conditions and competition, the petroleum industry, like many other large American industries, has been compelled to study ways and means of cheapening the cost of production and refining oil. The Bureau of Mines which maintains the largest research plant in the world devoted exclusively to the technology of petroleum, is rendering valuable assistance to the industry in the improvement of production and technical processes.

An outline of the various investigations now underway is given in complete detail in a recent extensive statement issued by the Department of Commerce.

INSTITUTE AND RELATED ACTIVITIES

The Atlanta Regional Meeting

The program of the Regional Meeting to be held at Atlanta, Ga., with headquarters at the Atlanta Biltmore, October 29-31, has now taken definite shape. Four technical sessions, one general session and a Student session are scheduled. Inspection trips and entertainment are also being planned. The complete program is given below.

Four general subjects will be covered in the technical sessions; namely, power development, power-system operation, communication and textile applications. There will be papers also on translations between sound and light, radio broadcasting, insulator flashover, dynamo design and photoelectric and glow-discharge devices.

The following general committee has charge of the meeting: C. O. Bickelhaupt, chairman; T. H. Landgraf, vice-chairman; C. E. Bennett, G. N. Brown, H. A. Coles, W. R. Collier, F. M. Craft, C. L. Emerson, T. W. Fitzgerald, E. H. Ginn, E. S. Hannaford, W. E. Mitchell, O. O. Rae, and G. J. Yundt.

The program of the meeting as now planned is as follows:

PROGRAM FOR ATLANTA REGIONAL MEETING OCTOBER 29-31

MONDAY MORNING, OCTOBER 29

Student Activities Session—Prof. E. S. Hannaford presiding:

Address of Welcome, C. O. Bickelhaupt (Vice-President, Southern District, A. I. E. E.) Southern Bell Tel. & Tel. Co.

Student Activities, H. H. Henline, Assistant National Secretary, A. I. E. E.

Five student papers on Student Activities.

General Discussion.

MONDAY AFTERNOON, OCTOBER 29

Power Developments Session:

Central Power Station Service, W. S. Lee, Duke Power Co.

Development and Operation of the Southeastern Power & Light System, A. T. Hutchins, Southeastern Power & Light Co.

Translations Between Sound and Light, J. B. Taylor, General Electric Co.

MONDAY EVENING, OCTOBER 29

General Session (public invited):

Presentation of Cup for Best Student Paper.

Introductory Remarks, P. S. Arkright.

The Existing Radio Problem, Judge E. O. Sykes.

Science and Research in Telephone Development, S. P. Grace, Bell Telephone Laboratories, Inc.

TUESDAY MORNING, OCTOBER 30

Communication Session:

Carrier-Current and Supervisory Control on Alabama Power Company's System, E. W. Robinson and W. I. Woodcock.

Line Characteristics for Carrier Communication, C. A. Boddie and R. C. Curtis, Westinghouse Electric & Mfg. Co.

Impulse Flashover of Insulators, J. J. Torok, Westinghouse Electric & Mfg. Co.

Magnetic Skin Effect in Dynamo Steel, D. P. Savant, Georgia School of Technology.

TUESDAY AFTERNOON, OCTOBER 30

Entertainment or Inspection Trips, probably ending with a Dinner-Dance.

WEDNESDAY MORNING, OCTOBER 31

Textile Session:

Variable-Speed Spinning of Cotton Yarns, E. A. Untersee, General Electric Co.

Motor Drives for Cards and Roving Frames, H. W. Reding, Westinghouse Electric & Mfg. Co.

Electrification of the Textile Industry in the Southeast.

a. *The Relation of the Public Utility to the Textile Mill*, A. G. Stanford, Robert and Company, Inc.

b. *Application of Electric Drive in the Textile Mill*, E. M. Clapp, Central Georgia Power Co.

WEDNESDAY AFTERNOON, OCTOBER 31

Power Operations Session:

Power-Limit Tests on the Southeastern Power and Light Company's System, Murray Jones and Robert Treat, General Electric Co.

Application of Auto-Oscillograph Equipment for Power Systems, A. Dovjikov, Westinghouse Electric & Mfg. Co.

Photoelectric and Glow-Discharge Devices, J. V. Breisky and E. O. Erikson, Westinghouse Electric & Mfg. Co.

Short-Circuit Testing on Alabama Power Company's System, Its Procedure and Effects on Operation, H. J. Scholz, Southeastern Engineering Co., and C. B. Hawkins, Alabama Power Co

The International Illumination Congress

As per announcement in July issue of the JOURNAL, sixty-one delegates, representing Austria, Australia, Brazil, Cuba, France, Germany, Great Britain, Holland, Japan, Switzerland, Italy and Russia, will assemble in New York City on about September 3, to attend the World's Congress on Illumination, and from September 5 to 17 will visit numerous cities in the northeastern section of the United States, Chicago being "farthest West" on the tour. Here, under the auspices of the Commonwealth Edison Co. they will be given opportunity to inspect a number of local installations such as the illumination of State Street in the loop district, the Buckingham Fountain in Grant Park, and of the billboard and sign lighting, which have no counterparts elsewhere; also a number of boulevard, park and street lighting installations which represent the most modern trend. Many other entertainment features are on the program for the two days in Chicago.

From Sept. 17 to 20 the twenty-second Annual Convention of the Illuminating Engineering Society will act as host to the delegates in a special technical and all-absorbing program as follows:

Monday morning, Sept. 17, following the address of welcome and other preliminary offices, there will be given the report of the Committee on Progress, followed in the afternoon by parallel sessions on Natural Lighting and Lighting Practise. Tuesday morning will be occupied by a Lighting Service session, paralleled with a Laboratory Session. Tuesday evening will be Ladies' Night with supper served at Hart House, demonstrating the lighting of home for special occasions, (Lillian E. Eddy), *L'Art Moderne in Lighting—The Development in Europe* (H. Maisonneuve and *L'Art Moderne in Lighting—The Echo from America*, (E. H. Bostock). Wednesday morning will be given over to a "European Lighting Session," followed in the afternoon by a General Session including the Report of the Committee on Lighting Legislation, *Fundamentals*, by L. Schneider, *General Lighting Plus*, by M. Luckiesh and *Lighting and Wiring Requisites for Convention Rooms*, by W. Sturrock. On Thursday morning, September 20, there will be a Lighting Practise Session, including the presentation of the Report of the Committee on Light and Safety, and papers entitled *The Illumination of Snellen Charts—an Investigation of Practise and Recommendations for Standardization, Artificial Light as an Aid to Surgery* and Illumination of Endless Caverns,—continued in the afternoon by a General Session at which will be presented the report of the Motor Vehicle Lighting Committee, and papers on the *Brightness of*

Street Surface as a Factor in Street Illumination, by Preston S. Millar, *An Investigation of Motor Vehicle Headlighting Requirements*, by H. C. Dickinson, and *The Transition in Lighting for Motion Picture Production*, by R. E. Farnham. There will be special exhibit of lighting equipment in a section of Convocation Hall at the University with many other plans for special entertainment and recreation for all in attendance.

After this Convention the foreign delegates will go to Saranac Inn, New York for a meeting of the International Commission on Illumination, Sept. 22-28.

Widespread Interest in National Fuels Meeting

The Second National Fuels Meeting will be held in the Cleveland Hotel, Cleveland, Ohio, on September 17 to 20, inclusive, under the auspices of the Fuels Division of The American Society of Mechanical Engineers. Registration headquarters will open early Sept. 17, 1928.

The first technical session will be held that afternoon. Sessions in industrial applications of fuels, heat transfer, powdered fuel, and a general session will mark the second days' activities.

Wednesday will be occupied with sessions on refractories and stokers, a session on marine practise, another on central station methods and progress and a series of papers treating with the fuel problems confronting the railroad men.

A very interesting program of plant inspection including the Fairmount Pumping Station of the Cleveland Water Works, the Avon Station of the Cleveland Electric Illuminating Company with modern central station consisting of six 3060-hp. Stirling "W" type boilers fired with powdered fuel and three General Electric 35,000-kw. turbo alternators, (said to be one of the most beautiful power stations in the country) and to three plants of the American Steel & Wire Company has been arranged by the local committee.

The final day will include a trip to the Cleveland Airport where special flying manoeuvres will be staged for the visitors. Other entertainment has been ably planned.

Revision of A. I. E. E. Transformer Standards

Section 13 of the A. I. E. E. Standards, "Transformers Induction, Regulators and Reactors" has been under revision for some time. The suggestions for bringing the standard up to date have been developed by a Transformer Subcommittee of the Electrical Machinery Committee and approved for distribution in report form by the Standards Committee for purposes of criticism and suggestion. The most radical change is one dealing with "Service Conditions." This was outlined in the August Journal, page 617. Pamphlet copies of the proposed revised Standard are now available and can be obtained without charge by addressed inquiries to H. E. Farrer, Secretary Standards Committee, A. I. E. E., 33 West 39th St., New York, N. Y.

Institution of Electrical Engineers Honors President Gherardi in London

In honor of President Gherardi, on July thirteenth the Institution of Electrical Engineers gave a luncheon at the Savoy Hotel, London. It was attended by 27 prominent electrical engineers.

Lt. Col. K. Edgcumbe, President-elect of the Institution, welcomed President Gherardi and referred to the joint session which the two societies had held by transatlantic radio on February 15, 1928. This in the future, he thought, would be considered a historic milestone, and he spoke in high terms of Mr. Gherardi's contribution to the success of the meeting.

President Gherardi responded, thanking the officers of the Institution of Electrical Engineers for the very cordial reception given him. He spoke of the work done by engineers as a class and the international character of engineering developments. The organization and activities of the A. I. E. E. were also outlined briefly.

Mr. W. M. Mordey, who was President of the Institution in 1908, mentioned the early developments in telephony, and said the importance of the connection of the two societies by radio telephone established in February will increase as time creates a better perspective.

A. I. E. E. Directors Meeting

The first meeting of the Board of Directors of the American Institute of Electrical Engineers for the administrative year beginning August 1, 1928 was held at Institute headquarters, New York, on Tuesday, August 7.

There were present: President R. F. Schuchardt, Chicago; Vice-Presidents A. B. Cooper, Toronto, E. B. Merriam, Schenectady, H. A. Kidder, New York; Directors I. E. Moultrop, Boston, H. C. Don Carlos, Toronto, F. C. Hanker, East Pittsburgh, E. B. Meyer, Newark, N. J., J. Allen Johnson, Niagara Falls, A. M. MacCutcheon, Cleveland; National Secretary F. L. Hutchinson, New York.

The minutes of the Directors Meeting held June 27, 1928, were approved.

A report of a meeting of the Board of Examiners held July 18, 1928 was presented, and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners, the following actions were taken: 22 Students were enrolled; 72 applicants were elected to the grade of Associate; three applicants were elected to the grade of Member; 19 applicants were transferred to the grade of Member; three applicants were transferred to the grade of Fellow.

Approval by the Finance Committee, for payment, of monthly bills amounting to $21,762.34, was ratified.

In accordance with Section 22 of the Constitution, the following "Members for Life" were exempted from future payment of dues: Frederick Bedell, E. R. Carichoff, Walter C. Fish, F. S. Hunting, Philip A. Lang, Frederick A. Scheffler, H. A. Sinclair.

Approval was given to the definite dates, May 7-9, 1929, for the Dallas Regional Meeting, District No. 7 (South West), previously authorized.

A petition to organize a Houston Section of the Institute was granted, to include all territory within sixty miles of Houston, Texas, plus the portion of Jefferson County lying outside the sixty-mile limit.

Announcement was made of the appointment by the President of committees and representatives of the Institute for the administrative year beginning August 1, 1928. (A complete list of committees and representatives appears elsewhere in this issue.)

In accordance with the By-laws of the Edison Medal Committee, the Board confirmed the appointment by the President of Mr. Samuel Insull as chairman of the Committee and of the following members of the Committee to serve for terms of five years each, ending July 31, 1933: Messrs. Charles F. Brush, D. C. Jackson, and Elmer A. Sperry. Also, conforming to the Committee's By-laws, the Board elected three of its own membership to serve on the Edison Medal Committee for terms of two years each, ending July 31, 1930, namely, Messrs. Bancroft Gherardi, H. A. Kidder, and E. B. Merriam.

Appointment by the President of the following members of the Lamme Medal Committee, in accordance with the By-laws of that Committee, was confirmed: Charles F. Scott (Chairman), H. H. Barnes, Jr., W. L. R. Emmet, C. F. Kettering, P. M. Lincoln, E. B. Meyer, L. W. W. Morrow, Elmer A. Sperry, and N. W. Storer.

The following Local Honorary Secretaries were reappointed for the two-year term commencing August 1, 1928: W. Elsdon-Dew (Transvaal), H. W. Flashman (Australia), A. S. Garfield (France), and F. W. Willis (India).

Recommendations of Student Branch Counselor delegates, adopted at a conference held in Denver, during the annua

Summer Convention, in June 1928, were presented and were approved or referred to the proper committees for consideration and recommendation. The following recommendations were adopted: (1) That the rules governing the award of Institute prizes be revised to provide that a paper, to be eligible for competition for the "Prize for Branch Paper," be based upon undergraduate work; and (2) that Section 57 of the By-laws be amended to include a statement that each Branch should nominate to the District Vice-President each year a faculty member for appointment as Counselor on August 1, but if any Branch has not submitted its nomination by July 1, the Vice-President in the District should make a recommendation for appointment to the President.

An invitation to be represented at the fourth meeting of the Southern Appalachian Power Conference to be held at Atlanta, October 8-10, 1928, was accepted. (Mr. W. E. Mitchell, of Atlanta, was later appointed as the Institute's delegate to this conference.)

Other matters were discussed, reference to which may be found in this and future issues of the JOURNAL.

Honorary Members

As announced in the July JOURNAL, the Board of Directors of the Institute at a meeting held in Denver June 27, 1928, elected five distinguished American engineers to Honorary Membership.

These elections have all been accepted as indicated by the following extracts from letters received:

THOMAS A. EDISON:

"I greatly appreciate the honor that has thus been conferred upon me, and I hereby beg to advise you of my acceptance of such election."

JOHN J. CARTY:

"This evidence of consideration on the part of my colleagues touches me deeply. It is a distinguished honor for which I shall always be grateful. Please convey to the Board of Directors my sentiments of sincere appreciation."

MICHAEL I. PUPIN:

"It is indeed a great honor to me to be an Honorary Member of an institution with which I have been connected for so many years, and this honor will be forever a source of much happiness to me. I accept the honor as a tribute to the sincere affection which was always a bond of union between the Institute and myself."

AMBROSE SWASEY:

"This high honor is greatly appreciated and I am very happy to accept. I am also much gratified to be one of the first Americans to receive this honor, and to be named with such notable engineers and scientists as Edison, Carty, Thomson and Pupin."

ELIHU THOMSON:

" I accept the membership, and assure you that I appreciate most deeply this honor, and congratulate the Directors on having chosen as the other candidates men of such high standing in electrical and kindred work.

I wish you would kindly convey to the Directors of the Institute my personal appreciation of the action taken. I should have been content to have continued as a member of the Institute."

Special Notice Regarding the Lamme Medal

Attention is called to a brief summary of the provisions for the annual award by the Institute of the Lamme Medal published on pages 618-19 of the JOURNAL for August 1928.

The time between the adoption of the By-laws of the Lamme Medal Committee and the date by which they provide that names should be submitted is so short that an extension has been made for this year, and the Committee will consider all names received by the National Secretary on or before October 15, 1928.

The Medal is to be awarded to a member of the Institute "who has shown meritorious achievement in the development of electrical apparatus or machinery."

Names of members of the Institute who are considered suitable candidates for the Lamme Medal may be submitted by any member in accordance with Section 1 of Article VI of the By-laws of the Committee, which was quoted in the item referred to above.

The New Institute of Chemistry

The Institute of Chemistry of the American Chemical Society, which closed its second session at Northwestern University, Evanston, Illinois, on August 18, has proved its usefulness both to academic and to industrial chemists, according to Director Frank C. Whitmore.

At Evanston hundreds of chemists from all over the country have listened to the up-to-date presentation of the latest developments in chemistry of every kind.

Much of the success of the Institute can be credited to Sir James Colquhoun Irvine, of the University of St. Andrews, Scotland. Sir James lectured to the Institute practically every day on the greatest variety of subjects, ranging from his own specialty of carbohydrates to problems in chemical education.

PERSONAL MENTION

WILL E. MELARKEY, formerly of Oakland, Calif., has removed to Honolulu where after October 1, he will represent the General Electric Company, with W. A. Ramsay, Ltd.

WILLIAM MCCLELLAN, Past-president of Institute and senior partner of McClellan & Junkersfeld, Inc. has merged his company with the Division of Construction and Engineering of Stone & Webster, Inc., under the new company name of Stone & Webster Engineering Corporation. Mr. McClellan will probably continue at his old address for several months.

GEORGE M. MARR has resigned his position as manager of Marine Sales with Chas. Cory & Son, Inc. and accepted a position as Director of Engineering and Sales, Department of Fire Protection Systems, Fyre-Freez Corporation, New York City. In his new position, Mr. Marr will specialize on the installation of Fire Detection and Fire Extinguishing Systems aboard ship.

PAUL C. SORSBY, for over fifteen years associated with the General Electric Company in various capacities, both in this country and abroad, announces he has opened an office in Augusta, Ga., specializing in electrical testing and maintenance work. Mr. Sorsby is one of the General Electric Company's veteran electrical construction and trouble men in Atlanta district.

Obituary

Johan Marinius Andersen, president of the Albert & J. M. Andersen Mfg. Co. of Boston, Mass. and an Associate of the Institute (1908) died July 25 in that city.

Mr. Andersen was a native of Norway, born November 28, 1855 at Barre. He came to the United States at an early age and in 1880 started his work with Albert Andersen of Boston. Until 1889 he designed and constructed various kinds of power presses, machinery and tools for working sheet metal and wire. He then became a partner of the firm of Albert & J. M. Andersen, which, in 1896 was reincorporated the Albert & J. M. Andersen Mfg. Company, with Mr. J. M. Andersen as treasurer. It was in 1889 that Mr. Andersen first undertook a study of the development of the electrical industry in the United States, designing and constructing many electrical apparatus including equipment for overhead electric railways, elevated and subway construc-

tions, switches, motor-operated and other electrical devices for use in power stations, manufacturing plants and elsewhere. For many years he served his own company as electrical engineer, also acting in a consulting capacity for the installation and construction of other electrical apparatus. He was a member of The American Society of Mechanical Engineers, the Engineers Club of Boston and the Boston Athletic Association.

Frank Rowland Shepherd, well known in electrical circles of New Zealand died suddenly at Auckland late in July.

Born at Ramsgate in 1872, Mr. Shepherd went to Australia as a young man, following electrical engineering in Sydney until 1901, when he removed to Dunedin. He superintended the construction of the Roslyn tramway scheme, said to be the first electric tramway installation in New Zealand, and later the tramway schemes for the Dunedin City Corporation. Some years ago he was appointed chief electrical inspector and advisor to the Fire Underwriters' Association of New Zealand with headquarters at Wellington. Mr. Shepherd was actively engaged in electrical work until a few months ago and during the course of his official duties visited practically all the electrical undertakings in the Dominion of New Zeland. He was also a member of the Wiremen's Registration Board, having filled a place on the board since its inception. He joined the Institute as an Associate in 1903, but in 1913 was transferred to the grade of Member.

Allen M. Schoen, chief engineer of the Southeastern Underwriters' Association and for the past fifteen years a Fellow of the Institute, died suddenly the morning of August 15, at his home in Atlanta, Georgia.

He was born at Richmond, Va., in 1869, and was graduated from the Virginia Military Institute as a civil engineer in 1889. He entered the railway service as a bridge construction engineer, but shortly thereafter gave up civil engineering and entered the shops of the General Electric Company. From 1889 to 1890 he was assistant in the office of the chief engineer of the Seaboard Air Line Railway and from February 1890 to the spring of 1891 was its Assistant Engineer of Construction.

Electrical work with the Taylor Electric Company of Richmond led in 1892 to his taking an expert course with the Thompson-Houston Electric Company, Lynn, Mass. From this work he returned to central station engineering in Georgia until August 1892 shortly thereafter becoming assistant superintendent of the Richmond Railway and Electric Company, Richmond, Va. Successive positions of Electrical Inspector, chief electrician and engineer and chief engineer were included in his work with the South Eastern Underwriters' Association until 1910. Taking up his electrical inspection work when the use of electricity was comparatively new, he played an important part in getting Southern cities and towns to adopt ordinances governing installation and important inspection requirements. He was author of Schoen's Manual of Electricity, designed chiefly as a guide to electricians and local electrical inspectors, and popular as a valuable contribution to electrotechnical literature.

Mr. Schoen was a charter member of the committee which formulated the national electrical code and served also upon the subsequent national electrical code committee of the National Board. He was a member of the governing committee of the Central Traction and Lighting Bureau and was for many years active in the National Fire Protection Association, of which last May he was elected president. For 15 years Mr. Schoen was doing general consulting engineering in the southern states with no inconsiderable practise in the special field of electrolysis. During the World War he attained the rank of a Class A Major of the Pioneer Engineers and was also a member of the Advisory Board of the United States Railroad Administration. He has served the Institute faithfully for many years in the varying capacities of Chairman of the Atlanta Section, several times Section Delegate, Manager 1906-1909 and from 1919 to 1920 one of its Vice-Presidents. He was an indefatigable worker possessed of a high sense of duty; a man who knew the meaning of opportunity and who made the most of every such occasion with painstaking, conscientious application to all matters, whether important or relatively insignificant.

William Maver, Jr., electrical engineer and expert in telegraphy in Jersey City and Fellow of the Institute since 1912, died August 8 at the age of 77.

Mr. Maver was born at Forfar, Scotland, but when he was but six years old, his parents moved to Montreal, where he received most of his schooling in electricity and the sciences. After serving in the Fenian raid campaign in 1865, for which he was the holder of a veteran's medal, he came in 1873 to New York to become electrical advisor for the Western Union Telegraph Company; later he was associated with the Safety Insulated Wire and Cable Company, the Consolidated Telegraph and Electrical Subway Company, the New York Heat, Light & Power Company and the Baltimore and Ohio Telegraph Company. He was owner of a publishing company bearing his name, a member of the New York Electrical Society, Association of Railway Telegraph Superintendents, Old Time Telegraphers and Historical Association, the New Jersey State Chess Association and St. Andrew's Society. From 1877 to 1879 he was captain of the American Athletic Club and was also a member of the Canadian Club of New York. Some of his contributions to technical literature are "The Quadruplex and Other Articles on Telegraphy" "Practical Systems of Electrical Telegraphy," "American Telegraphy and Encyclopaedia of the Telegraph," "Maver's Wireless Telegraphy and Telephony" and "Progress in Wireless Telephony." His text books have been in use in colleges and by the Signal Corps of the United States Army. Mr. Maver was counted an electrical public utility expert and was advisor in many electrical patent litigations.

John George Pertsch, Jr., Professor of Electrical Engineering, Cornell University and a member of the Institute since 1911, lost his life in attempt to rescue a young woman from drowning while in bathing August 24, 1928. His death was attributed to a sudden heart attack. Professor Pertsch was born in Baltimore, Md., December 1, 1887. His summer vacation in 1907 after graduating from the public schools of Baltimore, was spent in the repair shops and substations of the Consolidated Gas, Electric Light & Power Co. In 1908, he was electric power station attendant for the Consolidated Electric Company, Baltimore, and in 1909 the summer months, June toAugust inclusive, were spent in the Pittsburgh shops of the Westinghouse Electric & Mfg. Co., working on high-tension breakers. In 1909 he graduated from the Baltimore Polytechnic Institute, in Electrical Engineering and that year also obtained a degree of M. E. from Cornell University, to which he went in pursuit of graduate work in Electrical Engineering. From Sept. 1909 to June 1910 he was Assistant Instructor in the Department of Electrical Engineering at Cornell under Professor H. H. Norris, and that summer's vacation was spent in the Schenectady Works of the General Electric Company, testing alternating and continuous current generators and motors, and in the Fall he was chosen Instructor in "Theory and Characteristics of Electrical Machinery" at Cornell, under Professor Norris and Professor Karapetoff. Professor Gray of Cornell once said of Professor Pertsch, "He is one of my best assistant professors," and anyone knowing Professor Pertsch personally and acquainted with his unusual ability and application can well understand why this was true. Only the highest commendation has been given to all work which he has undertaken. He was a man of integrity, ability and application, and his loss will be deeply felt in all circles which his wide experience embraced. He was the author of "*Critical Review of the Bibliography on Unbalanced Magnetic Pull in Dynamo-Electric Machines*, A. I. E. E. TRANSACTIONS, Vol. 37, 1918, beside many contributions to the Sibley Journal of Engineering, a member of the Society for the Promotion of Engineering Education, a Sigma Xi, Eta Kappa Nu and Phi Kappa Phi fraternities.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, JULY 1 TO JULY 31, 1928

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

ANALYTIC GEOMETRY.

By R. L. Borger. N. Y., McGraw-Hill Book Co., 1928. 334 pp., diagrs., 7 x 5 in., cloth. $2.50.

The purpose of this book is to present the material so that the student will be led to acquire the habit of considering every problem from its geometric as well as its algebraic aspect, and to recognize that each throws a light upon the other.

BUSINESS CYCLES, THE PROBLEM AND ITS SETTING.

By Wesley C. Mitchell, N. Y. National Bureau of Economic Research, 1928. 489 pp., diagrs., 9 x 6 in., cloth. $6.50.

This book takes up current theories of business cycles, present day economic organizations, the analysis of modern statistical methods and business indexes, gives a summary of world-wide historical records and a working concept of business cycles.

The general plan of this work is similar to an earlier book on the subject by the same author, but the statistical data have proved so extensive that it will be published separately in a series of volumes instead of being included with the theoretical discussions.

CODE FOR ELECTRICITY METERS.

Prepared by a Sectional Committee according to the procedure of the American Engineering Standards Committee under the joint sponsorship of the Association of Edison Illuminating Companies, National Electric Light Association, United States Bureau of Standards. Third edition. N. Y., National Electric Light Association, 1928. 122 pp., 9 x 6 in., cloth. $2.00.

This third edition of the Code for Electricity Meters is a completely revised and rearranged compilation of the second edition, issued in 1912, and the section on Demand Meters, issued in 1920. The 1912-20 edition of the Code was approved as American standard by the American Engineering Standards Committee in July, 1922.

The main sections are as follows: Definitions; Standards; Metering; Specifications for Acceptance of Types of Electricity Meters; and Auxiliary Apparatus for Use with Meters; Installation Methods; Watthour Meter Tests Methods; Laboratory and Service Texts; and Demand Meters.

THE COLLOIDAL SALTS.

By Harry Boyer Weiser. N. Y., McGraw-Hill Book Co., 1928. 404 pp., diagrs., tables, 3 x 6 in., cloth. $5.00.

This book is a critical summary of the colloidal behavior of the salts with particular reference to their role in the study of colloid chemical phenomena and to the theory underlying their technical application. The first part of each section is devoted to a critical survey of the colloidal characteristics of the individual salts and the second part to the general theory of the applications which are concerned with their colloidal behavior. The volume is intended as an aid to students and research workers in both theoretical and applied science.

THE ELEMENTS OF ASTRONOMY.

By Edward Arthur Fath. 2nd Edition. N. Y., McGraw-Hill Book Co., 1928. 323 pp., illus., diagrs., 9 x 6 in., cloth. $3.00

This book is intended for college students who have had little mathematics. The metric system has been used throughout, but the English units are also given. This second edition includes all important advances to the end of 1927, and has a new set of star charts that have been prepared especially for this book.

THE ELEMENTS OF INDUSTRIAL ENGINEERING.

By George Hugh Shepard. Bost., Ginn and Co., 1928. 541 pp., diagrs., tables, 9 x 6 in., cloth. $4.80.

In the preparation of this work, the writer had three distinct purposes: (1) to reduce industrial engineering to a few definite and comprehensive principles by which the engineer can analyze any situation in management and synthesize the procedure; (2) to bring students immediately into working contact with these principles; and (3) to cause them to learn the principles practically by using them in their daily lives.

Some of the Chapter headings are as follows: III. Campus activities as a part of a student's education. V. Adaptation of conditions and work to each other. IX. Higher Common Sense. XI. Personnel. XII. Organization. XIII. Standards. XV. The Fair Deal.

ELEMENTS OF PHYSICS.

By A. Wilmer Duff and Henry T. Weed. N. Y. Longmans, Green and Co., 1928. 565 pp. illus., diagrs., 8 x 5 in., cloth. $2.20.

In this elementary text book on physics, the authors have placed a few questions after each paragraph in order to test the student's understanding of what has been read. Exercises and problems are given at the end of each chapter, and pictures of the applications of physical principles have been included in order to awaken interest in physics as a study.

ENGINEERS.

N. Y., Neo-Techni Research Corporation, 1928. Illus., diagrs., tables. 12 x 9 in., cloth. $25.00.

This book lists the engineers in corporations with their official duties and connections. It gives the essential engineering data for each branch of engineering, and a directory of materials and equipment for industrial and power plants. There is also a section devoted to mathematical tables and a list of universities of engineering with the names of the presidents and the engineering faculty. The book is divided into five sections, separately paged.

ENGINEERING AERODYNAMICS.

By Walter S. Diehl. (Ronald Aeronautic Library) N. Y. Ronald Press Co., 1928. 298 pp., illus., diagrams, 9 x 6 in., cloth. $5.00.

This book has been written to supply the demand for more practical information on aerodynamics in form suitable for direct application by aircraft designers and advanced students in aeronautical engineering. The author has tried to include as much new material as possible and to avoid the inclusion of well-known or easily obtained data. The conventional treatment of elementary aerodynamical problems has been omitted.

INTERMEDIATE ELECTRICITY AND MAGNETISM.

By R. A. Houstoun. Lond., Longmans, Green and Co., 1928. 170 pp., illus., diagrs., 8 x 5 in., cloth. $1.75.

This work is intended for use in intermediate grades of universities. Each chapter is followed by a set of problems and at the end of the book are given examination questions from the intermediate examinations at London University.

THE LINEMAN'S HANDBOOK.

By Edwin Kurtz. N. Y., McGraw-Hill Book Co., 1928. 547 pp., illus., diagrs., tables, 8 x 5 in., cloth. $4.00.

This book is written especially for linemen, foremen and other employees of line departments. It is intended for home study, covering construction and maintenance procedure and methods. The author has avoided technical terms as far as possible, and a large number of illustrations showing the various steps in the operations described, has been provided to assist the reader to understand the text.

MATHEMATICS IN LIBERAL EDUCATION.

By Florian Cajori. Bost., Christopher., Publishing House, 1928. 8 x 5 in., cloth. $1.50.

This book is a review of the statements of prominent men of all ages on the effect of mathematics in liberal education. In this historical study of the question, the author has quoted names and opinions of those in favor of mathematics as well as those opposed to mathematics.

MODERN PICTURE THEATER ELECTRICAL EQUIPMENT AND PROJECTION.

By R. V. Johnson. 2nd Edition. Lond., Crosby Lockwood and Son, 1927. 189 pp., illus., diagrams, 9 x 6 in., cloth. 10/6.

This is not a scientific textbook, but is intended for architects, theater owners, theater operators and electricians. It takes up primary, secondary and effect lighting of theaters, the motion picture projection room and projection machine, with all the necessary electrical equipment.

PETROLEUM AND ITS PRODUCTS.

By William A Gruse. N. Y., McGraw-Hill Book Co., 1928. 377 pp., 9 x 6 in., cloth. $4.50.

This book starts with a general description of the types of petroleum, their chemical constitution, physical properties and origin. The author then discusses refining by distillation, chemical methods, absorption and cracking. The last part includes gasoline and motor fuels, kerosene, lubrication and petroleum lubricants, petroleum wax and petrolatum, fuel oil, petroleum asphalts and miscellaneous petroleum products. It is intended as a textbook on the chemistry of American petroleum.

THE PHYSICS OF CRYSTALS.

By Abram F. Joffe. Edited by Leonard B. Loeb. N. Y. McGraw-Hill Book Co., 1928. 198 pp., diagrs., 9 x 6 in., cloth. $3.00.

This book comprises a series of lectures given at the University of California, and contains the results of investigations carried on for the last twenty-five years. It covers a limited portion of the field of the elastic and electrical properties of solids. It gives the phenomena that tend to confirm the electrical theory of crystals, and the phenomena that, although they do not contradict the theory, are not completely explained by it.

RADIOAKTIVITAT.

By Stefan Meyer and Egon Schweidler. 2nd edition. Leipzig, B. G. Teubner, 1927. 721 pp., diagrs., tables, 9 x 6 in., cloth. 36 rm.

This book discusses the processes in radio active transformation and radiation and the methods of measuring it. The various radio active substances are included as well as the subject of radio activity in geophysics and cosmo-physics. Bibliographies are given at the end of each section.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ELECTRICAL ENGINEER, young, as physicist with analytical mind and preferably with experience on induction disk motors, research and development group. Apply by letter. Salary $300 a month. Location, East. X-5170.

RECENT GRADUATES in electrical engineering or in physics who have had some experience in meter work and instruments, and who wish to specialize therein. Work of the laboratory covers practically the entire field of electrical measurements. Opportunity for advancement. Apply by letter, giving complete details of education, training and experience. Location, East. X-5543.

MEN AVAILABLE

ELECTRICAL ENGINEER. Technical training, 19 years' experience in industrial power applications in steel mills. Capable of laying out substations, switchboards, cable systems and motor applications, including specifications for equipment required. Desires a position in the engineering or power department of a large industrial company. Location preferred, Middle West. C-4847.

ELECTRICAL ENGINEER, graduate of University of Colorado last June, desires a position in an engineering organization, manufacturing or utility company which will lead toward advancement to executive position. Location, immaterial; West preferred. C-4855.

GRADUATE ELECTRICAL ENGINEER, 34, married, 11 years' experience, desires position in operating department of public utility or in applied research department with industrial concern. Location, immaterial. B-7223.

ELECTRICAL ENGINEER, E. E. degree, desires position with public utility or engineering

concern requiring executive ability and an analytical mind. Twelve years' experience covering engineering design and valuation of power plants, substations, transmission and distribution systems. Available immediately. Location, East. B-389.

ELECTRICAL ENGINEER, graduate, 22, single, and in A-1 health, good draftsman, sales personality and a year's experience on Westinghouse Test, desires a permanent position with a public utility, mining or manufacturing company. Willing to start on a moderate salary. Location, immaterial. Excellent references and available on two weeks' notice. C-3678.

MECHANICAL, ELECTRICAL ENGINEER, registered New Jersey and Pennsylvania, M. I. T. graduate, married, American ancestry. Valuable experience handling men, reoganizing and reducing costs, especially necessary, non-productive departments; design, construction, maintenance metal working, textile factories; steam, water power plants, fire protection, heating, ventilating, lighting, electric power; rerouting, material handling, cost analysis, engineering statistics, etc. B-5714.

CONSTRUCTION MANAGER, graduate, 15 years' public utility experience, open for connection as construction manager, chief engineer, operating executive for operating company. Can bring complete, experienced organization, financial, clerical and technical, to handle construction force of 500 men on power plant, transmission line and substation construction. A-2191.

APPRAISAL ENGINEER, expert; graduate electrical engineer; 10 years' experience compiling detail cost analyses, construction estimates, inventories and valuations of plants and equipment owned by electric and gas public utilities for bankers reports, classified accounting systems, continuous physical property records, rate and capitalization cases. Formerly with New York State Public Service Commission. B-9636.

ELECTRICAL AND MECHANICAL ENGINEER, 34, married. Technical University graduate, 5 years' experience in design and construction of power plants and substations, 2 years responsible position with electrical railway, 3 years public utility. Practical type of man. Speaks and writes French and German fluently, working knowledge of Spanish. Ability to handle men. Now employed, available on reasonable notice. C-4046.

ELECTRICAL ENGINEER, 35, married. Rensselaer Poly. Inst. graduate, having broad experience in Public Utility work consisting of management, design, construction and operation. Qualifications good for a supervising engineer or district manager. C-4936.

ELECTRICAL ENGINEER, American, 48 years old. Street railway, main line electrification, mining and public utilities. 20 years in Latin America as engineer and manager. Did considerable Diesel engine and refrigeration work. B-5912.

ELECTRICAL ENGINEER, 29, married, five years with Western Electric Company, Switchboard Department; three years with utility company, construction of power plant and 33-kv. and 66-kv. substations. Experience in installation of carrier current telephone and metallic telephone for transmission. Location, United States. C-4831.

MECHANICAL ENGINEER, 24, graduate of Cornell University with two years' of boiler room and plant maintenance experience in a water-gas plant of 20,000,000 cu. ft. capacity, wants permanent position with engineering firm. C-1769.

ELECTRICAL ENGINEER, 23, married, graduate E. E. Hydroelectric, steam plant and extensive test experience; one year distribution engineering, overhead lines; employed at present by large utility; desires position affording opportunity for advancement with reasonable compensation. Available on short notice. Good references. Location, immaterial. C-4921.

ELECTRICAL ENGINEER, 23, B. S. in E. E., from University of Wisconsin, 1928, desires position with good opportunity for advancement. Lack of experience compensated for by eagerness to learn employers methods. Available immediately. Location, preferred, United States. C-4905.

MANUFACTURING EXECUTIVE seeks connection with a future. Graduate in both Electrical and Mechanical Engineering. Eight years' experience on design of small electrical apparatus. Two years as manufacturing engineer of a large department. Six years as production manager of a large plant. Thoroughly experienced in handling labor and controlling modern manufacture. C-4587.

ELECTRICAL COMMUNICATION TEACHING OR RESEARCH. Age, 30, married. Three and a half years at Bell Telephone Laboratories. Ph.D. in Physics with special attention to acoustics and electricity. One year technical writing, reporting current communication developments. Qualified to give graduate and undergraduate communication courses and do research on audio-frequency problems. C-4919.

ELECTRICAL MECHANICAL ENGINEER, graduate, 25, single. One year Business Administration Course. Two years' experience in Electrical Railroad, Power Stations, construction, testing, design. At present connected with Consulting Engineers doing Railroad Evaluation. Speaks French, German, Spanish. Location, South America or Europe. C-4892.

ELECTRICAL ENGINEER, 31, graduate, Norwegian. Two years' experience in substation, power plant equipment, such as shop work on power transformers, relay testing, structure, switchboard diagrams; 1½ years' experience as electrical engineer, Westinghouse, electric locomotive equipment. Desires position in Engineering department of public utility company or electric railway concern. Speaks French and German. Excellent references. C-4942.

ELECTRICAL ENGINEERING GRADUATE, eight years out of college, with experience in General Electric Test Course, designing and layout of outdoor substations, switching structures and distribution, desires position. B-8622.

AVAILABLE FOR ENGINEERING-BUSINESS CONNECTION. Technical graduate, 29, B. S., E. E., 1923, with business school training and five years of electrical manufacturing and electric utility experience, invites preliminary correspondence for the confidential exchange of additional information relative to positions of an engineering-business nature. Utility, industrial, investment banking. Now employed. B-8991.

STEAM AND HYDROELECTRIC DESIGNER, 34, married. Technical graduate eleven years' experience on design, construction and operation of large steam and hydro-electric power plants from preliminary designs and estimates to completed plant. Desires permanent position in responsible charge of work. Location, immaterial. C-4868.

ELECTRICAL ENGINEER, 31, graduate, married; 6 years' high tension, substation, transmission line layout, design, material; 2 years with architect, complete plants, specifications, engineering, wiring for light, power, signals, for theaters, office buildings, hotels, apartments; 1 year full charge electrical installations big buildings for contractor. Qualify as estimating engineer anywhere in United States. B-4217.

EXECUTIVE OR ELECTRICAL ENGINEER, 40, married. 14 years' experience covering design, construction and maintenance, distribution and transmission systems, substations and generating systems, equipment sales, purchases, statistics and special reports. Desires connection with public utility or manufacturing concern. Southern or Central States preferred. B-9480.

ELECTRICAL ENGINEER AND SUPERVISOR, 32, broad experience with utilities in both office and field, desires new connection in responsible position, such as assistant manager or electrical superintendent. Excellent record. Available at short notice. Salary $3600. B-5505.

ELECTRICAL ENGINEER, 25, single, desires position with public utility or industrial concern. Two years drafting and designing of central and substations with public utility company; two years drafting and designing of central and substation and electrical installations for lumber mills and factories with industrial concern; one year as assistant electrical engineer with manufacturing company. C-3713.

SALES EXECUTIVE, 40, graduate electrical engineer with commercial school training, Westinghouse apprenticeship, eight years' factory and construction experience, nine years' very successful sales and executive experience in mechanical and electrical lines. Pleasing personality, good organizer, able to handle men. Extensively traveled, well read, speaks Spanish and French. B-3065.

ELECTRICAL-MECHANICAL ENGINEER with fifteen years' broad engineering, construction and maintenance experience. Experience covers hydroelectric, industrial, textile, refrigeration and machine shop. Not a college graduate but can furnish excellent references as to character and ability. Available on short notice. Salary open to negotiation B-8601.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before September 30, 1928.

Baker, J. R., Pennsylvania Water & Power Co., Baltimore, Md.
Beck, B., United Metal Box Co., Brooklyn, N. Y.
Betancor-Suarez, A., (Member), Compania Cubana de Electricidad, Havana, Cuba
Bouvier, G. A., (Member), Western Electric Co., Inc., Chicago, Ill.
Bozic, A J., American Gas & Electric Co., New York, N. Y.
Brace, P. H., Westinghouse Elec. & Mfg. Co., Co., Pittsburgh, Pa.
Campbell, E. O., Brooklyn Edison Co., Brooklyn, N. Y.
Carr, J. P., Department of City Transit, Philadelphia, Pa.
Conard, W., Board of Transportation, Long Island City, N. Y.
Conner, J. C., U. S. Engineers Office, War Dept., Washington, D. C.
Dick, S., The Okonite Co., Dallas, Texas
Draffin, G. F., Westinghouse International Electric Co., East Pittsburgh, Pa.

Durfee, I. W., Commonwealth Utilities Corp., Denver, Colo.
Engel, G. H., Thos. E. Murray, Inc., New York, N. Y.
Falck, K. J. C., I. T. E. Circuit Breaker Co., Philadelphia, Pa.
Feick, C. G. E., Northern Electric Co., Montreal, Que., Can.
Fishberg, S., Aerovox Wireless Corp., Brooklyn, N. Y.
Flatman, G. J., (Member), Ohio Electric Power Co., Sidney, Ohio
Gedanic, J. F., Premier Red Ash Coal Corp., Red Ash, Va.
Goutink, N. J., 3729 93rd St., Elmhurst, N. Y.
Halliday, U. N., Pacific Electric Mfg. Corp., Portland, Ore.
Hamilton, S., Eiseman Magneto Corp., Brooklyn, N. Y.
Herold, A. J., Electric Distribution, City of Fairbury, Fairbury, Nebr.
Iwe, H. G., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Jordan, A. H., General Electric Co., West Philadelphia, Pa.
Kaplan, L. J., Coverdale & Colpitts, New York, N. Y.
Klatte, A. J., (Member), Chicago Surface Lines, Chicago, Ill.
Liebert, H., Brooklyn Manhattan Transit Co., Brooklyn, N. Y.
Miller, R. C., Pennsylvania Power & Light Co., Wilkes-Barre, Pa.
Miramontes, F. C., Office of City Engineer, Redwood City, Calif.
Morgan, A. B., National Electric Light Association, New York, N. Y.
Morro, J. J., City Radio Stores, New York, N. Y.
Nixon, G. M., Electric Storage Battery Co., New York, N. Y.
Rockwell, G. O., Commonwealth Utilities Corp., Denver, Colo.
Scanlon, J. L., Electrical Sales Engineer, Buffalo, N. Y.
Sears, J. J., Brooklyn Edison Co., Brooklyn, N. Y.
Slack, R. C., Appalachian Electric Power Co., Charleston, West Va.
Smith, B. J., Williamsburg Power Plant Corp., Brooklyn, N. Y.
Soderberg, C. R., (Member), Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Soukaras, K. M., 101 W. 58th St., New York, N. Y.
Spraggon, J. H., Westinghouse Elec. & Mfg. Co., New Haven, Conn.
Squires, W. H., Oil Production, Casey, Ill.
Watson, A. D., Delacarlia Hydroelectric Plant, Washington, D. C.
Weber, V. G., Myers Electric Works, Portland, Ore.
Wilson, C. T. R., Yamachiche Baum Sta., Canadian Marconi Co., Montreal, Que., Can.
Total 45.

Foreign

de Sousa, A. M., Sao Paulo Tramway, Light & Power Co., Ltd., Sao Paulo, Brazil, S. A.
Grant, L. C., (Fellow), Merz & McLellan, Newcastle-on-Tyne, Eng.
Gray, W. T., South Otago Freezing Co., Balclutha, N. Z.
Heath, J. G., Motueka Borough Council, Motueka, N. Z.
Monkhouse, A., (Member), Chief Engr. in U.S.S.R., Metropolitan-Vickers Electrical Co., Leningrad, Russia
Taylor, E. O., City & Guilds College, S. Kensington, London, S. W. 7, Eng.
Rao, K. V. Post & Tel. Dept., F. M. S. & S. S., Penang, India
Total 7.

STUDENTS ENROLLED

Abas, Joseph A., University of Detroit
Annand, George E., Engg. School of Milwaukee
Babb, Maynard, A., Mass. Inst. of Technology
Benjamin, Archie, McGill University
Felger, Gerald K., Engg. School of Milwaukee
Ficken, Ralph J., Engg. School of Milwaukee
Gray, Claude M., Engg. School of Milwaukee
Hanson, Edward E., Engg. School of Milwaukee
Kraft, Walter R., Engg. School of Milwaukee
Lehman, Ralph J., University of Detroit
Lord, Ralph, University of Detroit
Ramsay, Henry B., Engg. School of Milwaukee
Remsburg, Marshall L., Engg. School of Milwaukee
Rippere, R. Oliver, Brooklyn Polytechnic Inst.
Schwendler, Crawford, Engg. School of Milwaukee
Sosinsky, Lewis, University of Manitoba
Stack, Wilbert E., University of Detroit
Stevens, Chester, Engg. School of Milwaukee
Stoeckly, Eugene E., University of Colorado
Sullivan, Emmet J., University of Detroit
Thurm, Richard W., Engg. School of Milwaukee
Werwarth, Karol O., Engg. School of Milwaukee
Total 22.

Officers of the A. I. E. E., 1928-1929

PRESIDENT

(Term expires July 31, 1929)
R. F. SCHUCHARDT

JUNIOR PAST PRESIDENTS

(Term expires July 31, 1929) C. C. CHESNEY
(Term expires July 31, 1930) BANCROFT GHERARDI

VICE-PRESIDENTS

(Terms expire July 31, 1929)
O. J. FERGUSON (District No. 6)
E. R. NORTHMORE (District No. 8)
J. L. BEAVER (District No. 2)
A. B. COOPER (District No. 10)
C. O. BICKELHAUPT (District No. 4)

(Terms expire July 31, 1930)
E. B. MERRIAM (District No. 1)
H. A. KIDDER (District No. 3)
W. T. RYAN (District No. 5)
B. D. HULL (District No. 7)
G. E. QUINAN (District No. 9)

DIRECTORS

(Terms expire July 31, 1929)
M. M. FOWLER
E. C. STONE
CHARLES E. STEPHENS

(Terms expire July 31, 1930)
I. E. MOULTROP
H. C. DON CARLOS
F. J. CHESTERMAN

(Terms expire July 31, 1931)
F. C. HANKER
E. B. MEYER
H. P. LIVERSIDGE

(Terms expire July 31, 1932)
J. ALLEN JOHNSON
A. M. MacCUTCHEON
A. E. BETTIS

NATIONAL TREASURER / **NATIONAL SECRETARY**

(Terms expire July 31, 1929)
GEORGE A. HAMILTON — F. L. HUTCHINSON

HONORARY SECRETARY
RALPH W. POPE

GENERAL COUNSEL
PARKER & AARON
30 Broad Street, New York

PAST PRESIDENTS—1884-1928

*Norvin Green, 1884-5-6.
*Franklin L. Pope, 1886-7.
*T. Commerford Martin, 1887-8.
Edward Weston, 1888-9.
Elihu Thomson, 1889-90.
*William A. Anthony, 1890-91.
*Alexander Graham Bell, 1891-2.
Frank Julian Sprague, 1892-3.
*Edwin J. Houston, 1893-4-5.
*Louis Duncan, 1895-6-7.
*Francis Bacon Crocker, 1897-8.
A. E. Kennelly, 1898-1900.
*Carl Hering, 1900-1.
*Charles P. Steinmetz, 1901-2.
Charles F. Scott, 1902-3.
Bion J. Arnold, 1903-4.
John W. Lieb, 1904-5.
*Schuyler Skaats Wheeler, 1905-6.
*Samuel Sheldon, 1906-7.
*Henry G. Stott, 1907-8.
Louis A. Ferguson, 1908-9.
Lewis B. Stillwell, 1909-10.
Dugald C. Jackson, 1910-11.
Gano Dunn, 1911-12.
Ralph D. Mershon, 1912-13.
C. O. Mailloux, 1913-14.
Paul M. Lincoln, 1914-15.
John J. Carty, 1915-16.
H. W. Buck, 1916-17.
E. W. Rice, Jr., 1917-18.
Comfort A. Adams, 1918-19.
Calvert Townley, 1919-20.
A. W. Berresford, 1920-21.
William McClellan, 1921-22.
Frank B. Jewett, 1922-23.
Harris J. Ryan, 1923-4.
Farley Osgood, 1924-25.
M. I. Pupin, 1925-26.
C. C. Chesney, 1926-27.
Bancroft Gherardi, 1927-28.

*Deceased.

LOCAL HONORARY SECRETARIES

T. J. Fleming, Calle B. Mitre 519, Buenos Aires, Argentina, S. A.
H. W. Flashman, Aus. Westinghouse Elec. Co. Ltd., Cathcart House, 11 Castlereagh St., Sydney, N. S. W., Australia.
Frederick M. Servos, Rio de Janeiro Tramways Lt. & Pr. Co., Rio de Janeiro, Brazil, S. A.
Charles le Maistre, 28 Victoria St., London, S. W. 1, England.
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E., France.
F. W. Willis, Tata Power Companies, Bombay House, Bombay, India.
Guido Semenza, 39 Via Monte Napoleone, Milan, Italy.
P. H. Powell, Canterbury College, Christchurch, New Zealand.
Axel F. Enstrom, 24a Grefturegatan, Stockholm, Sweden.
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa.

A. I. E. E. Committees

GENERAL STANDING COMMITTEES

EXECUTIVE COMMITTEE

R. F. Schuchardt, Chairman, 72 West Adams St., Chicago, Ill.
C. C. Chesney, G. A. Hamilton, E. B. Meyer, Bancroft Gherardi, H. A. Kidder, I. E. Moultrop.

FINANCE COMMITTEE

E. B. Meyer, Chairman, 80 Park Place, Newark, N. J.
H. A. Kidder, C. E. Stephens.

MEETINGS AND PAPERS COMMITTEE

H. P. Charlesworth, Chairman, 195 Broadway, New York, N. Y.
E. H. Hubert, Secretary, 33 W. 39th St., New York.
A. E. Knowlton, E. B. Meyer, H. S. Osborne, A. M. MacCutcheon, L. W. W. Morrow, C. E. Skinner, J. E. Macdonald, T. A. Worcester.
Chairman of Committee on Coordination of Institute Activities, *ex-officio.*
Chairmen of Technical Committees, *ex-officio.*

PUBLICATION COMMITTEE

W. S. Gorsuch, Chairman, 600 West 59th Street, New York, N. Y.
H. P. Charlesworth, F. L. Hutchinson, E. B. Meyer, Donald McNicol.

COMMITTEE ON COORDINATION OF INSTITUTE ACTIVITIES

H. A. Kidder, Chairman, 600 West 59th St., New York, N. Y.
C. O. Bickelhaupt, W. S. Gorsuch, W. B. Kouwenhoven, H. P. Charlesworth, F. L. Hutchinson, E. B. Meyer.

BOARD OF EXAMINERS

E. H. Everit, Chairman, Southern New England Tel. Co., New Haven, Conn.
F. J. Chesterman, Erich Hausmann, L. W. W. Morrow, H. W. Drake, A. H. Kehoe, S. D. Sprong, Harold Goodwin, G. L. Knight, John B. Taylor, S. P. Grace, J. B. Whitehead.

SECTIONS COMMITTEE

W. B. Kouwenhoven, Chairman, Johns Hopkins University, Baltimore, Md.
J. D. Ball, J. L. Beaver, W. S. Rodman, G. E. Quinan,
Chairmen of Sections, *ex-officio.*

COMMITTEE ON STUDENT BRANCHES

J. L. Beaver, Chairman, Lehigh University, Bethlehem, Pa.
Edward Bennett, A. B. Gates, W. E. Wickenden, Charles F. Scott,
Student Branch Counselors, *ex-officio.*

MEMBERSHIP COMMITTEE

J. E. Kearns, Chairman, General Electric Co., 230 South Clark St., Chicago, Ill.

Vice-Chairmen

G. O. Brown, John B. Fisken, S. H. Mortensen, F. E. Dellinger, J. J. Frank, Joseph Showalter, Herbert B. Dwight, C. R. Jones, G. J. Yundt, G. M. Keenan,

Ex-officio

Chairmen of Section Membership Committees.

HEADQUARTERS COMMITTEE

R. H. Tapscott, Chairman, 124 East 15th Street, New York, N. Y.
F. L. Hutchinson, E. B. Meyer.

LAW COMMITTEE

C. O. Bickelhaupt, Chairman, Southern Bell Tel. & Tel. Co., Atlanta, Ga.
M. M. Fowler, Paul M. Lincoln, E. C. Stone, A. G. Pierce,

PUBLIC POLICY COMMITTEE

D. C. Jackson, Chairman, 31 St. James Ave., Boston, Mass.
H. W. Buck, Gano Dunn, John W. Lieb, C. C. Chesney, F. B. Jewett, Harris J. Ryan.

STANDARDS COMMITTEE

F. D. Newbury, Chairman, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
H. E. Farrer, Secretary, 33 W. 39th St., New York.
C. M. Gilt, A. M. MacCutcheon, V. M. Montsinger, C. R. Harte, J. F. Meyer, C. E. Skinner, H. A. Kidder, W. I. Slichter.

Ex-Officio

President, U. S. National Committee of I. E. C.
Chairmen of Working Committees.
Chairmen of delegations on other standardizing bodies.

EDISON MEDAL COMMITTEE

Appointed by the President for term of five years.

(Terms expire July 31, 1929)
N. A. Carle, Charles L. Edgar, John W. Lieb.
(Terms expire July 31, 1930)
George Gibbs, Samuel Insull, Chairman, Ralph D. Mershon.
(Terms expire July 31, 1931)
John W. Howell, L. F. Morehouse, David B. Rushmore.
(Terms expire July 31, 1932)
E. B. Craft, Paul M. Lincoln, C. E. Skinner.
(Terms expire July 31, 1933)
Charles F. Brush, D. C. Jackson, Elmer A. Sperry.

Elected by the Board of Directors from its own mmbership for term of two years.

(Terms expire July 31, 1929)
H. P. Liversidge, E. B. Meyer, I. E. Moultrop.
(Terms expire July 31, 1930)
B. Gherardi, H. A. Kidder, E. B. Merriam.

Ex-Officio

R. F. Schuchardt, President, George A. Hamilton, National Treasurer, F. L. Hutchinson, National Secretary.

LAMME MEDAL COMMITTEE

(Terms expire July 31, 1929)
W. L. R. Emmet, C. F. Kettering, Elmer A. Sperry.
(Terms expire July 31, 1930)
P. M. Lincoln, E. B. Meyer, L. W. W. Morrow.
(Terms expire July 31, 1931)
H. H. Barnes, Jr., Charles F. Scott, Chairman N. W. Storer.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT

H. B. Smith, Chairman, Worcester Polytechnic Institute, Worcester, Mass.
A. H. Babcock, F. B. Jewett, H. P. Liversidge, G. Faccioli, John W. Lieb, J. B. Whitehead.

COMMITTEE ON COLUMBIA UNIVERSITY SCHOLARSHIPS

W. I. Slichter, Chairman, Columbia University, New York, N. Y.
Francis Blossom, H. C. Carpenter.

COMMITTEE ON AWARD OF INSTITUTE PRIZES

H. P. Charlesworth, Chairman, 195 Broadway, New York, N. Y.
W. S. Gorsuch, F. W. Peek, Jr.

COMMITTEE ON SAFETY CODES

F. V. Magalhaes, Chairman, N. Y. Edison Co., 708 First Avenue, New York, N.Y.
A. E. Bettis, Philander Betts, J. E. Brobst, L. L. Elden, J. C. Forsyth, H. B. Gear, J. P. Jackson, H. W. Leitch, M. G. Lloyd, Wills Maclachlan, R. W. E. Moore, W. T. Morrison, R. H. Nexsen, H. R. Sargent, W. H. Sawyer, H. S. Warren.

SPECIAL COMMITTEES

LICENSING OF ENGINEERS

Francis Blossom, Chairman, 52 William Street, New York, N. Y.
H. W. Buck, Gano Dunn, E. W. Rice, Jr., L. E. Imlay,

ADVISORY COMMITTEE TO THE MUSEUMS OF THE PEACEFUL ARTS

J. P. Jackson, Chairman, 130 East 15th Street, New York, N. Y.
R. H. Nexsen, George K. Thompson.

TECHNICAL COMMITTEES

AUTOMATIC STATIONS

W. H. Millan, Chairman, 2615 Clifton Ave., St. Louis, Mo.
P. H. Adams, Caesar Antoniono, L. D. Bale, C. A. Butcher, M. S. Coover, H. C. Don Carlos, P. E. Hart, Joseph Hellenthal, Chester Lichtenberg, S. J. Lisberger, G. H. Middlemiss, O. Naef, E. W. Seeger, L. J. Turley, F. Zogbaum.

COMMUNICATION

H. W. Drake, Chairman, Western Union Telegraph Co., 195 Broadway, New York, N. Y.
G. R. Benjamin, H. P. Charlesworth, F. J. Chesterman, L. W. Chubb, J. L. Clarke, R. N. Conwell, B. R. Cummings, Charles E. Davies, R. D. Evans, E. H. Everit, D. H. Gage, S. P. Grace, Erich Hausmann, P. J. Howe, H. L. Huber, B. D. Hull, G. A. Kositzky, F. H. Kroger, Ray H. Manson, R. D. Parker, S. R. Parker, F. A. Raymond, C. A. Robinson, J. K. Roosevelt, H. A. Shepard, John F. Skirrow, H. M. Turner, F. A. Wolff.

EDUCATION

Edward Bennett, Chairman, University of Wisconsin, Madison, Wis.
E. W. Allen, J. L. Beaver, H. W. Buck, V. Bush, O. J. Ferguson, A. B. Gates, W. B. Hartshorne, Paul M. Lincoln, C. E. Magnusson, W. E. Mitchell, H. S. Osborne, A. G. Pierce, C. S. Ruffner, W. S. Rugg, W. E. Wickenden.

ELECTRICAL MACHINERY

W. J. Foster, Chairman, General Electric Co., Schenectady, N. Y.
E. B. Paxton, Secretary, General Electric Co., Schenectady, N. Y.
P. L. Alger, B. L. Barns, A. B. Cooper, W. M. Dann, C. M. Gilt, W. S. Gorsuch, S. L. Henderson, B. G. Jamieson, J. Allen Johnson, A. H. Kehoe, C. W. Kincaid, H. C. Louis, A. M. MacCutcheon, V. M. Montsinger, F. D. Newbury, J. M. Oliver, A. M. Rossman, R. B. Williamson.

ELECTRIC WELDING

A. M. Candy, Chairman, Westinghouse E. & M. Co., East Pittsburgh, Pa.
C. A. Adams, P. P. Alexander, C. W. Bates, Ernest Bauer, Alexander Churchward, O. H. Eschholz, H. M. Hobart, C. J. Holslag, C. L. Ipsen, J. C. Lincoln, Ernest Lunn, A. M. MacCutcheon, J. W. Owens, Wm. Spraragen.

ELECTROCHEMISTRY AND ELECTROMETALLURGY

G. W. Vinal, Chairman, Bureau of Standards, Washington, D. C.
Lawrence Addicks, Arthur N. Anderson, T. C. Atchison, Farley G. Clark, Safford K. Colb, E. B. Dawson, F. A. J. Fitzgerald, F. C. Hanker, W. E. Holland, F. A. Lidbury, G. Schluederberg, J. A. Seede, Magnus Unger, J. B. Whitehead, E. A. Williford, J. L. Woodbridge.

ELECTROPHYSICS

V. Karapetoff, Chairman, Cornell University, Ithaca, N. Y.
O. E. Buckley, V. Bush, John R. Carson, F. M. Clark, W. D. Coolidge, W. F. Davidson, O. J. Ferguson, C. L. Fortescue, A. Hund, Carl Kinsley, W. B. Kouwenhoven, K. B. McEachron, R. A. Millikan, R. H. Park, L. J. Peters, J. Slepian, F. E. Terman.

Liaison Representatives of American Physical Society
Dr. W. F. G. Swann, Prof. A. P. Wills

GENERAL POWER APPLICATIONS

J. Frank Gaskill, Chairman, 1000 Chestnut Street, Philadelphia, Pa.
D. H. Braymer, C. W. Drake, Harry L. Grant, Clyde D. Gray, C. Francis Harding, E. W. Henderson, Geo. H. Jones, P. C. Jones, A. C. Lanier, A. M. Lloyd, A. M. MacCutcheon, W. S. Maddocks, N. L. Mortensen, E. B. Newill, K. A. Pauly, D. M. Petty, H. W. Price, H. L. Smith, A. H. Stebbins, E. C. Stone, W. H. Timbie, F. M. Weller, M. R. Woodward, W. C. Yates.

INSTRUMENTS AND MEASUREMENTS

Everett S. Lee, Chairman, General Electric Co., Schenectady, N. Y.
O. J. Bliss, Perry A. Borden, W. M. Bradshaw, H. B. Brooks, A. L. Cook, Melville Eastham, W. N. Goodwin, Jr., F. C. Holtz, I. F. Kinnard, A. E. Knowlton, H. C. Koenig, W. B. Kouwenhoven, E. B. Merriam, W. J. Mowbray, T. E. Penard, R. T. Pierce, E. J. Rutan, G. A. Sawin, R. W. Sorensen, H. M. Turner.

APPLICATIONS TO IRON AND STEEL PRODUCTION

M. M. Fowler, Chairman, General Electric Co., 230 So. Clark St., Chicago, Ill.
A. C. Bunker, F. B. Crosby, A. C. Cummins, S. L. Henderson, A. M. MacCutcheon, O. Needham, K. A. Pauly, A. G. Pierce, A. G. Place, F. O. Schnure, J. W. Speer, G. E. Stoltz, Wilfred Sykes, T. S. Towle, J. D. Wright.

PRODUCTION AND APPLICATION OF LIGHT

B. E. Shackelford, Chairman, Westinghouse Lamp Co., Bloomfield, N. J.
W. T. Blackwell, J. R. Cravath, W. T. Dempsey, Lewis Fussel, G. C. Hall, L. A. Hawkins, H. H. Higbie, C. L. Kinsloe, A. S. McAllister, G. S. Merrill, P. S. Millar, F. H. Murphy, F. A. Rogers, W. T. Ryan, W. M. Skiff, C. J. Stahl, G. H. Stickney.

APPLICATIONS TO MARINE WORK

W. E. Thau, Chairman, Westinghouse E. & M. Co., 150 Broadway, New York, N. Y.
Edgar C. Alger, R. A. Beekman, H. C. Coleman, E. M. Glasgow, H. F. Harvey, Jr., C. J. Henschel, Wm. Hetherington, Jr., H. L. Hibbard, A. Kennedy, Jr., J. B. Lunsford, E. B. Merriam, I. H. Osborne, G. A. Pierce, Wm. H. Reed, Edgar P. Slack, H. M. Southgate, Oscar A. Wilde, J. L. Wilson, R. L. Witham.

APPLICATIONS TO MINING WORK

Carl Lee, Chairman, 1652 McCormick Bldg., Chicago, Ill.
A. R. Anderson, F. N. Bosson, Graham Bright, M. M. Fowler, E. J. Gealy, L. C. Isley, G. M. Kennedy, R. L. Kingsland, A. B. Kiser, W. H. Lesser, John A. Malady, C. H. Matthews, F. C. Nicholson, W. F. Schwedes, F. L. Stone, E. B. Wagner, J. F. Wiggert, C. D. Woodward.

POWER GENERATION

F. A. Allner, Chairman, Pennsylvania Water & Power Co., Lexington Building, Baltimore, Md.
J. R. Baker, Secretary, Pennsylvania Water & Power Co., Lexington Building, Baltimore, Md.
A. E. Bettis, J. B. Crane, P. M. Downing, James H. Ferry, N. E. Funk, W. S. Gorsuch, F. C. Hanker, C. F. Hirshfeld, A. H. Hull, A. H. Kehoe, H. A. Kidder, G. L. Knight, W. H. Lawrence, W. S. Lee, F. T. Leilich, James Lyman, E. B. Meyer, W. E. Mitchell, I. E. Moultrop, F. A. Scheffler, W. F. Sims, A. R. Smith, E. C. Stone, R. W. Stovel, William M. White.

POWER TRANSMISSION AND DISTRIBUTION

H. R. Woodrow, Chairman, Brooklyn Edison Co., Inc., Pearl and Willoughby Sts., Brooklyn, N. Y.

R. E. Argersinger,	E. W. Dillard,	E. R. Northmore,
Geo. M. Armbrust,	R. E. Doherty,	L. L. Perry,
R. W. Atkinson,	L. L. Elden,	T. F. Peterson,
E. T. J. Brandon,	R. D. Evans,	D. W. Roper,
V. Bush,	F. M. Farmer,	A. E. Silver,
P. H. Chase,	Harland C. Forbes,	L. G. Smith,
C. V. Christie,	C. L. Fortescue,	H. C. Sutton,
D. D. Clarke,	K. A. Hawley,	Percy H. Thomas,
W. H. Cole,	V. L. Hollister,	Philip Torchio,
R. N. Conwell,	J. P. Jollyman,	Theodore Varney,
M. T. Crawford,	A. H. Kehoe,	H. L. Wallau,
W. A. Del Mar	A. H. Lawton,	H. S. Warren,
Herbert H. Dewey,	W. E. Mitchell,	R. J. C. Wood.

PROTECTIVE DEVICES

E. A. Hester, Chairman, 435 Sixth Avenue, Pittsburgh, Pa.

Raymond Bailey,	James S. Hagan,	R. L. Kingsland,
V. J. Brain,	H. Halperin,	M. G. Lloyd,
A. C. Cummins,	F. C. Hanker,	R. C. Muir,
E. W. Dillard,	F. L. Hunt,	N. L. Pollard,
H. W. Drake,	B. G. Jamieson,	A. M. Rossman,
W. S. Edsall,	J. Allen Johnson,	A. H. Schirmer,
L. E. Frost,	S. M. Jones,	E. R. Stauffacher,
E. E. George,		H. R. Summerhayes.

RESEARCH

F. W. Peek, Jr., Chairman, General Electric Company, Pittsfield, Mass.

H. D. Arnold,	J. A. Johnson,	D. W. Roper,
Edward Bennett,	V. Karapetoff,	Clayton H. Sharp,
V. Bush,	A. E. Kennelly,	C. E. Skinner,
E. H. Colpitts,	S. M. Kintner,	R. W. Sorensen,
W. F. Davidson,	M. G. Lloyd,	T. S. Taylor,
W. P. Dobson,	Chester W. Rice,	J. B. Whitehead.

TRANSPORTATION

W. M. Vandersluis, Chairman, 1201 S. Michigan Avenue, Chicago, Ill.

Reinier Beeuwkes,	W. K. Howe,	Ralph H. Rice,
A. E. Bettis,	D. C. Jackson,	N. W. Storer,
J. V. B. Duer,	John Murphy,	Richard H. Wheeler,
E. R. Hill,	W. S. Murray,	Sidney Withington,
	W. B. Potter,	

A. I. E. E. Representatives

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE COUNCIL

M. I. Pupin, Gano Dunn.

AMERICAN BUREAU OF WELDING

H. M. Hobart.

AMERICAN COMMITTEE ON ELECTROLYSIS

B. J. Arnold, N. A. Carle, F. N. Waterman.

AMERICAN ENGINEERING COUNCIL ASSEMBLY

H. H. Barnes, Jr.,	H. M. Hobart,	*Farley Osgood,
A. W. Berresford,	F. L. Hutchinson,	A. G. Pierce,
C. C. Chesney,	*H. A. Kidder,	E. W. Rice, Jr.,
F. J. Chesterman,	William McClellan,	*Charles F. Scott,
*John H. Finney,	L. F. Morehouse,	*C. E. Skinner,
*M. M. Fowler,	I. E. Moultrop,	Calvert Townley.

*Members of Administrative Board.

AMERICAN ENGINEERING STANDARDS COMMITTEE

J. F. Meyer, John C. Parker, C. E. Skinner.
H. M. Hobart, H. S. Osborne, L. T. Robinson, Alternates.

AMERICAN MARINE STANDARDS COMMITTEE

R. A. Beekman

AMERICAN YEAR BOOK, ADVISORY BOARD

Henry H. Henline

BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY

H. P. Charlesworth, H. A. Kidder, G. L. Knight,

CHARLES A. COFFIN FELLOWSHIP AND RESEARCH FUND COMMITTEE

R. F. Schuchardt

COMMITTEE OF APPARATUS MAKERS AND USERS, NATIONAL RESEARCH COUNCIL

C. E. Skinner

COMMITTEE ON ELIMINATION OF FATIGUE, SOCIETY OF INDUSTRIAL ENGINEERS

C. Francis Harding

COMMITTEE ON HEAT TRANSMISSION, NATIONAL RESEARCH COUNCIL

T. S. Taylor

ENGINEERING FOUNDATION BOARD

Gano Dunn, L. B. Stillwell.

JOHN FRITZ MEDAL BOARD OF AWARD

C. C. Chesney, Bancroft Gherardi, M. I. Pupin.
Farley Osgood,

JOINT COMMITTEE ON WELDED RAIL JOINTS

D. D. Ewing, A. P. Way.

JOINT CONFERENCE COMMITTEE OF FOUNDER SOCIETIES

The Presidents and Secretaries, *ex-officio*.

LIBRARY BOARD OF UNITED ENGINEERING SOCIETY

Edward D. Adams, F. L. Hutchinson, W. B. Jackson,
E. B. Craft, W. I. Slichter.

NATIONAL FIRE PROTECTION ASSOCIATION, ELECTRICAL COMMITTEE

F. V. Magalhaes, W. T. Morrison, Alternate

NATIONAL FIRE WASTE COUNCIL

John H. Finney, F. V. Magalhaes.

NATIONAL RESEARCH COUNCIL, ENGINEERING DIVISION

Cary T. Hutchinson, F. B. Jewett, S. M. Kintner,
F. L. Hutchinson, *ex-officio*.

NATIONAL SAFETY COUNCIL, ELECTRICAL COMMITTEE OF A. S. S. E.—ENGINEERING SECTION

F. V. Magalhaes

THE NEWCOMEN SOCIETY

E. B. Craft

RADIO ADVISORY COMMITTEE, BUREAU OF STANDARDS

A. E. Kennelly

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION BOARD OF INVESTIGATION AND COORDINATION

Gano Dunn, Frank B. Jewett.

U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL COMMISSION ON ILLUMINATION

A. E. Kennelly, C. O. Mailloux, Clayton H. Sharp.

U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

E. W. Allen,	F. V. Magalhaes,	L. T. Robinson,
W. A. Del Mar,	C. O. Mailloux,	D. W. Roper,
Gano Dunn,	William McClellan,	R. F. Schuchardt, (*ex-officio*)
F. C. Hanker,	E. B. Meyer, (*ex-officio*)	C. H. Sharp,
H. M. Hobart,	J. F. Meyer,	C. E. Skinner,
D. C. Jackson,	F. D. Newbury, (*ex-officio*)	W. I. Slichter,
F. B. Jewett,	H. S. Osborne,	A. R. Stevenson, Jr.
A. E. Kennelly,	Farley Osgood,	N. W. Storer,
H. A. Kidder,	F. W. Peek, Jr.,	Elihu Thomson,
John W. Lieb,	E. W. Rice, Jr.,	John W. Upp.

WASHINGTON AWARD, COMMISSION OF

L. A. Ferguson, Charles F. Scott.

LIST OF SECTIONS

Name	Chairman	Secretary
Akron	John Grotzinger	H. C. Paiste, No. Ohio Pr. & Lt. Co., Akron, Ohio
Atlanta	T. H. Landgraf	D. H. Woodward, Amer. Tel. & Tel. Co., 938 Hurt Bldg., Atlanta, Ga.
Baltimore	W.B.Kouwenhoven	R. T. Greer, Cons. Gas Elec. Lt. & Pr. Co., Lexington Bldg., Baltimore, Md.
Boston	H. B. Dwight	G. J. Crowdes, Simplex Wire & Cable Co., Sidney Street, Cambridge, Mass.
Chicago	B. E. Ward	T. G. Le Clair, Commonwealth Edison Co., Rm. 822, 72 W. Adams St., Chicago, Ill.
Cincinnati	R. C. Fryer	L. O. Dorfman, Westinghouse E. & M. Co., 3rd & Elm Sts., Cincinnati, Ohio
Cleveland	E. W. Henderson	P. D. Manbeck, National Carbon Co., Madison Ave. & West 117th St., Cleveland, Ohio
Columbus	W. E. Metzger	R. A. Brown, 87 E. Dunedin Road, Columbus, Ohio
Connecticut	E. J. Amberg	R. G. Warner, Yale Univ., 10 Hillhouse Ave., New Haven, Conn.
Dallas	G. A. Mills	A. Chetham-Strode, Dallas Pr. & Lt. Co., Interurban Bldg., Dallas, Texas
Denver	L. N. McClellan	R. B. Bonney, Telephone Bldg., P. O. Box 960, Denver, Colo.
Detroit-Ann Arbor	A. H. Lovell	L. F. Hickernell, Commonwealth Power Corp., 212 Michigan Avenue, West, Jackson, Mich.

Name	Chairman	Secretary
Erie	M. L. Elder	A. W. Wennerstrom, General Electric Co., Erie, Pa.
Fort Wayne	C. F. Beyer	J. F. Eitman, 1841 Broadway, Ft. Wayne, Ind.
Indianapolis-Laf.	Herbert Kessel	Stanley S. Green, Indiana Electric Corp., Guaranty Bldg., Indianapolis, Ind.
Ithaca	R. F. Chamberlain	H. H. Race, School of Elec. Engg., Cornell University, Ithaca, N. Y.
Kansas City	B. J. George	A. B. Covey, Southwestern Bell Tel. Co., Kansas City, Mo.
Lehigh Valley	H. D. Baldwin	E. F. Weaver, Pa. Pr. & Lt. Co., 901 Hamilton St., Allentown, Pa.
Los Angeles	H. L. Caldwell	N. B. Hinson, Southern Cal. Edison Co., 3rd and Broadway, Los Angeles, Cal.
Louisville	E. D. Wood	N. C. Pearcy, Louisville Gas & Electric Co., 311 W. Chestnut St., Louisville, Ky.
Lynn	Charles Skoglund	V. R. Holmgren, Turbine Engg. Dept., G. E. Co. Bldg. 64 G, Lynn, Mass.
Madison	L. J. Peters	L. C. Larson, Dept. of Elec. Engg., University of Wisconsin, Madison, Wisconsin
Mexico	B. Nikiforoff	E. D. Luque, Providencia 520, Colonia Del Valle, Mexico D. F., Mexico
Milwaukee	E. R. Stoekle	R. R. Knoerr, Engr., Knoerr & Fischer, 553 Milwaukee St., Milwaukee, Wis.
Minnesota	J. E. Sumpter	Gilbert Cooley, Northern States Pr. Co., 807 Lincoln Bank Bldg., Minneapolis, Minn.
Nebraska	C. D. Robison	C. L. Skarolid, Room 1303, Telephone Bldg., Omaha, Neb.
New York	R. H. Tapscott	H. S. Sheppard, Dept. of Dev. & Research, Amer. Tel. & Tel. Co., 195 Broadway, New York, N. Y.
Niagara Frontier	G. H. Calkins	E. P. Harder, Buffalo General Electric Co., 205 Electric Bldg., Buffalo, N. Y.
Oklahoma	C. V. Bullen	C. W. Walter, Dept. of Elec. Engg., Univ. of Oklahoma, Norman, Okla.
Panama	L. W. Parsons	M. P. Benninger, Box 174, Balboa Heights, C. Z.
Philadelphia	I. M. Stein	R. H. Silbert, Philadelphia Electric Co., 2301 Market St., Philadelphia, Pa.
Pittsburgh	H. E. Dyche	J. A. Cadwallader, The Bell Telephone Co. of Pa., 416 7th Ave., Pittsburgh, Pa.
Pittsfield	J. R. Rue	V. M. Montsinger, General Electric Co., Pittsfield, Mass.
Portland, Ore.	L. M. Moyer	H. H. Cake, Pacific State Elec. Co., 5th and Davis Streets, Portland, Ore.
Providence	A. E. Watson	F. W. Smith, Blackstone Valley Gas & Elec. Co., Pawtucket, R. I.
Rochester	H. Gordon	C. F. Estwick, c/o General Railway Signal Co., Rochester, N. Y.
St. Louis	C. P. Potter	E. G. McLagan. 2188 Railway Exchange Bldg., St. Louis, Mo.
San Francisco	B. D. Dexter	A. G. Jones, General Electric Co., 804 Russ Bldg., San Francisco, Calif.
Saskatchewan	E. W. Bull	W. P. Brattle, Dept. of Tels., Telephone Bldg., Regina, Sask., Canada
Schenectady	E. S Lee	E. E. Johnson, Room 435, Bldg. No. 2, General Electric Co., Schenectady, N. Y.
Seattle	C. R. Wallis	Ray Rader, Puget Sound Pr. & Lt. Co., Seattle, Wash.
Sharon	H. B. West	J. B. Gibbs, Westinghouse Electric & Mfg. Co., Sharon, Pa.
Southern Virginia	W. S. Rodman	J. S. Miller, Box 12, University, Va.
Spokane	Bernhard Olsen	H. L. Vincent, N. 1417 Washington St., Spokane, Washington
Springfield, Mass.	J. F. Murray	B. V. K. French, Am. Bosch Magneto Corp., Springfield, Mass.
Syracuse	W. R. McCann	F. E. Verdin, 615 City Bank Bldg., Syracuse, N. Y.
Toledo	W. T. Lowery	Max Neuber, 1257 Fernwood Ave. Toledo, Ohio
Toronto	C. E. Sisson	F. F. Ambuhl, Toronto Hydro-Elec. System, 226 Yonge St., Toronto, Ont., Canada
Urbana	J. O. Kraehlenbuehl	J. K. Tuthill, 106 Transportation Bldg., University of Ill., Urbana, Ill.
Utah	D. L. Brundige	C. B. Shipp, General Elec. Co., 200 S. Main St., Salt Lake City, Utah
Vancouver	C. W. Colvin	J. Teasdale, British Columbia Elec. Railway Co., Vancouver, B. C., Canada
Washington	L. D. Bliss	R. W. Cushing, Federal Pr. Comm., Interior Bldg., 18th & F Sts., N. W., Washington, D. C.
Worcester	A. F. Snow	F. B. Crosby, Morgan Constr. Co., 15 Belmont St., Worcester, Mass.
Total 53		

LIST OF BRANCHES

Name and Location	Chairman	Secretary	Counselor (Member of Faculty)
Akron, Municipal University of, Akron, Ohio	C. R. Delagrange	P. W. Bierman	J. T. Walther
Alabama Polytechnic Institute, Auburn, Ala	W. P. Smith	C. W. Meyer	W. W. Hill
Alabama, University of, University, Ala			
Arizona, University of, Tucson, Ariz	J. H. Hopper	Audley Sharpe	J. C. Clark
Arkansas, University of, Fayetteville, Ark	W. H. Mann, Jr.	Dick Ray	W. B. Stelzner
Armour Institute of Technology, 3300 Federal St., Chicago, Ill	L. J. Anderson	H. T. Dahlgren	D. P. Moreton
Brooklyn Polytechnic Institute, 99 Livingston St., Brooklyn, N. Y	H. F. Steen	F. J. Mullen	
Bucknell University, Lewisburg, Pa	R. E. Snauffer		W. K. Rhodes
California Institute of Technology, Pasadena, Calif	G. R. Crane	A. W. Dunn	R. W. Sorensen
California, University of, Berkeley, Calif	H. H. Hyde	H. K. Morgan	T. C. McFarland
Carnegie Institute of Technology, Pittsburgh, Pa	G. M. Cooper	J. H. Ferrick	B. C. Dennison
Case School of Applied Science, Cleveland, Ohio	W. A. Thomas	J. O. Herbster	H. B. Dates
Catholic University of America, Washington, D. C			
Cincinnati, University of, Cincinnati, Ohio	C. E. Young	W. C. Osterbrock	W. C. Osterbrock
Clarkson College of Technology, Potsdam, N. Y		C. H. Joy	A. R. Powers
Clemson Agricultural College, Clemson College, S. C	A. P. Wylie	W. J. Brogdon	S. R. Rhodes
Colorado State Agricultural College, Fort Collins, Colo	Harold Groat	Howard Steinmetz	H. G. Jordan
Colorado, University of, Boulder, Colo	H. R. Arnold	E. E. Stoeckly	W. C. DuVall
Cooper Union, New York, N. Y	E. T. Reynolds	Wilfred Henschel	
Denver, University of, Denver, Colo	J. N. Petrie	D. S. Cooper	R. E. Nyswander
Detroit, University of, Detroit, Mich	E. T. Faur	Wm. F. Haldeman	H. O. Warner
Drexel Institute, Philadelphia, Pa	D. M. Way	C. W. Kenyon	E. O. Lange
Duke University, Durham, N. C	W. E. Cranford	C. W. Berglund, Jr.	W. J. Seeley
Florida, University of, Gainesville, Fla	A. W. Payne	N. J. Rogers	J. M. Weil
Georgia School of Technology, Atlanta, Ga		K. W. Mowry	E. S. Hannaford
Idaho, University of, Moscow, Idaho	O. C. Mayer		J. H. Johnson
Iowa State College, Ames, Iowa	R. R. Law	C. E. Rohrig	F. A. Fish
Iowa, State University of, Iowa City, Iowa	F. L. Kline	M. B. Hurd	A. H. Ford
Kansas State College, Manhattan, Kansas	H. C. Lindberg	J. E. Schwanke	
Kansas, University of, Lawrence, Kans	A. E. Keefe		G. C. Shaad
Kentucky, University of, Lexington, Ky	H. M. Otto	D. M. James	W. E. Freeman
Lafayette College, Easton, Pa	J. W. Dagon	H. W. Lovett	Morland King
Lehigh University, Bethlehem, Pa	S. R. Van Blarcom	R. S. Taylor	J. L. Beaver
Lewis Institute, Chicago, Ill	A. Gaimari		F. A. Rogers
Louisiana State University, Baton Rouge, La	R. C. Alley	Henry Joyner	M. B. Voorhies
Louisville, University of, Louisville, Ky	Samuel Evans	J. S. Overstreet	D. C. Jackson, Jr.
Maine, University of, Orono, Maine	A. V. Smith	G. A. Whittier	W. E. Barrows, Jr.
Marquette University, 1200 Sycamore St., Milwaukee, Wis	J. R. Adriansen	H. J. Lavigne	J. F. H. Douglas
Massachusetts Institute of Technology, Cambridge, Mass	R. M. Durrett		W. H. Timbie
Michigan State College, East Lansing, Mich	M. H. Blevin	W. G. Keck	M. M. Cory
Michigan, University of, Ann Arbor, Mich	W. R. Hough	H. L. Scofield	B. F. Bailey
Milwaukee, School of Engineering of, 415 Marshall St., Milwaukee, Wis	G. E. Henkel		J. D. Ball
Minnesota, University of, Minneapolis, Minn	G. C. Brown	G. C. Hawkins	H. Kuhlmann
Mississippi Agricultural & Mechanical College, A. & M. College, Miss	R. S. Kersh		L. L. Patterson
Missouri School of Mines & Metallurgy, Rolla, Mo	H. H. Brittingham	E. J. Gregory	
Missouri, University of, Columbia, Mo	C. E. Schooley	W. D. Johnson	M. P. Weinbach
Montana State College, Bozeman, Mont		G. E. Henkel	J. A. Thaler
Nebraska, University of, Lincoln, Neb	G. W. Cowley	L. T. Anderson	F. W. Norris
Nevada, University of, Reno, Nevada	Alden McCullom		S. G. Palmer
Newark College of Engineering, 367 High St., Newark, New Jersey	C. P. Hurd		

LIST OF BRANCHES—*Continued.*

Name and Location	Chairman	Secretary	Counselor (Member of Faculty)
New Hampshire, University of, Durham, N. H.	N. J. Pierce	M. W. Cummings	L. W. Hitchcock
New York, College of the City of, 139th St. & Convent Ave., New York, N. Y.	Daniel Klatzko	Walter Broleen	Harry Baum
New York University, University Heights, New York, N. Y.	G. A. Taylor	A. W. Schneider	
North Carolina State College, Raleigh, N. C.	O. M. Carpenter	W. E. Moseley	C. W. Ricker
North Carolina, University of, Chapel Hill, N. C.			
North Dakota, University of, University Station, Grand Forks, N. D.	Alfred Botten	Nels Anderson	D. R. Jenkins
Northeastern University, 316 Huntington Ave., Boston 17, Mass.	R. W. Cleveland	H. F. Wilder	W. L. Smith
Notre Dame, University of, Notre Dame, Ind.	Charles Topping	George Conner	J. A. Caparo
Ohio Northern University, Ada, Ohio	R. F. Rice	R. A. Lash	I. S. Campbell
Ohio State University, Columbus, O.	R. H. Spry	G. W. Trout	F. C. Caldwell
Ohio University, Athens, O.	Clarence Kelch	H. W. Giesecke	A. A. Atkinson
Oklahoma A. & M. College, Stillwater, Okla.	Benny Fonts	J. D. Robertson, Jr.	Edwin Kurtz
Oklahoma, University of, Norman, Okla.	Dick Mason	J. S. Harmon	
Oregon State College, Corvallis, Ore.	Harry Loggan	A. W. Swingle	F. O. McMillan
Pennsylvania State College, State College, Pa.		J. F. Houldin	L. A. Doggett
Pennsylvania, University of, Philadelphia, Pa.		H. W. Brown, Jr.	C. D. Fawcett
Pittsburgh, University of, Pittsburgh, Pa.	K. A. Wing	R. H. Perry	H. E. Dyche
Princeton University, Princeton, N. J.	R. W. MacGregor, Jr.	W. Wilson	Malcolm MacLaren
Purdue University, Lafayette, Indiana	J. F. Nuner	P. C. Sandretto	A. N. Topping
Rensselaer Polytechnic Institute, Troy, N. Y.	S. E. Benson		F. M. Sebast
Rhode Island State College, Kingston, R. I.			Wm. Anderson
Rose Polytechnic Institute, Terre Haute, Ind.		G. P. Brosman	C. C. Knipmeyer
Rutgers University, New Brunswick, N. J.	John Cost	H. M. Hobson	
Santa Clara, University of, Santa Clara, Calif.	R. P. O'Brien	C. E. Newton	L. J. Neuman
South Dakota State School of Mines, Rapid City, S. D.	L. M. Becker	R. Mytinger, Jr.	J. O. Kammerman
South Dakota, University of, Vermillion, S. D.	C. R. Cantonwine	Paul Schell	B. B. Brackett
Southern California, University of, Los Angeles, Calif.	Lester Bateman	L. F. Slezak	P. S. Biegler
Stanford University, Stanford University, Calif.	N. R. Morgan	W. G. Snyder	T. H. Morgan
Stevens Institute of Technology, Hoboken, N. J.	W. N. Goodridge	S. J. Tracy	F. C. Stockwell
Swarthmore College, Swarthmore, Pa.	T. C. Lightfoot	B. C. Algeo	Lewis Fussell
Syracuse University, Syracuse, N. Y.	E. D. Lynde	R. C. Miles	C. W. Henderson
Tennessee, University of, Knoxville, Tenn.			C. A. Perkins
Texas, A. & M. College of, College Station, Texas		H. L. Wilke	C. C. Yates
Texas, University of, Austin, Texas	Ab Martin	H. A. Tankersley	J. A. Correll
Utah, University of, Salt Lake City, Utah	N. M. Chapman	Garnett Littlefield	H. E. Mendenhall
Vermont, University of, Burlington, Vt.	F. L. Sulloway	L. G. Cowles	L. P. Dickinson
Virginia Military Institute, Lexington, Va.	Lomax Gwathmey	R. A. Wright	S. W. Anderson
Virginia Polytechnic Institute, Blacksburg, Va.	M. B. Cogbill	A. G. Colllins	Claudius Lee
Virginia, University of, University, Va.	C. E. McMurdo	L. R. Quarles	W. S. Rodman
Washington, State College of, Pullman, Wash.	H. B. Tinling	J. B. Danielson	R. D. Sloan
Washington University, St. Louis, Mo.		W. L. Knaus	H. G. Hake
Washington, University of, Seattle, Wash.	Wm. Bolster	Arthur Peterson	G. L. Hoard
Washington and Lee University, Lexington, Va.	R. E. Kepler	Bernard Yoepp, Jr.	R. W. Dickey
West Virginia University, Morgantown, W. Va.	G. B. Pyles	C. C. Coulter	A. H. Forman
Wisconsin, University of, Madison, Wis.		Alva Sweet	C. M. Jansky
Worcester Polytechnic Institute, Worcester, Mass.	F. J. McGowan, Jr.	H. P. Shreeve	E. W. Starr
Wyoming, University of, Laramie, Wyoming	J. O. Yates	E. C. Moudy	G. H. Sechrist
Yale University, New Haven, Conn.	R. W. Miner	J. R. Sutherland	C. F. Scott
Total 98			

AFFILIATED STUDENT SOCIETY

Brown Engineering Society, Brown University, Providence, R. I. .... S. A. Woodruff

ORDER FORM FOR REPRINTS OF PAPERS ABRIDGED IN THE JOURNAL

(September 1928) Number	Author	Title
☐ **28-96**	M. S. Coover and W. D. Hardaway	Transmission Experience of the Public Service Company of Colorado
☐ **28-62**	W. W. Lewis	Relation between Transmission Line Insulation and Transformer Insulation
☐ **28-67**	Philip Sporn	Rationalization of Transmission System Insulation Strength
☐ **28-90**	R. W. Lindsay	Utilization of Lodgepole Pine Timber for Poles
☐ **28-54**	R. A. Hentz	Electrical Features of Conowingo Generating Station and the Receiving Stations in Philadelphia
☐ **28-56**	A. Wilson	The Conowingo Hydroelectric Development
☐ **28-119**	C. F. King, Jr	Power Supply for Railway Signals
☐ **28-86**	H. W. Drake, Chairman	Report of Committee on Electrical Communication
☐ **28-103**	P. Torchio, Chairman	Report of Committee on Transmission and Distribution
☐ **28-97**	Preston S. Millar, Chairman	Report of Committee on Production and Application of Light

Name...

Address...

Please order reprints by number *Adress* **Order Department A. I. E. E., 33 West 39th Street, New York, N. Y.**

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Oil Circuit Breakers.—Bulletin 473, 4 pp. Describes Condit type MO 1 motor operated closing mechanism for oil switches and circuit breakers. Bulletin 458-3, 4 pp. describes switch houses for outdoor service. These are used to provide protection for switching equipment where the power required is too small to justify the erection of a substation. Condit Electrical Manufacturing Corporation, Boston, Mass.

Grounding Methods.—Bulletin 70, 24 pp. A comprehensive treatise on grounding methods for power house supply stations and large industrial plant installations. Power grounding equipment and ground testing meters are described. Borden Electric Company, 480 Broad Street, Newark, N. J.

Network Protectors and Relays.—Instruction Book I. B. 5414, on Westinghouse type CM-2 network protectors and relays. Besides giving complete instructions for the installation and care of this equipment the book is useful as a source of information to engineers and others interested in the application of network protection. Four different types of protectors are covered by this book, namely, 500, 800, 1200 and 1600 ampere capacities. Illustrations include diagrams and photos of the apparatus and also numerous drawings showing operating characteristics. Westinghouse Electric & Manufacturing Company, East Pittsburgh.

High Tension Switches.—Bulletin 15, 20 pp. Describes Pacific Electric types "Y" and "YS" switches for voltages up to and including 220 kv. These switches are a development of many years of switch manufacturing of this design, embodying features that have proved valuable in the older designs, and which have been standardized for uniformity in the present type. Pacific Electric Manufacturing Corporation, 5815 Third Street, San Francisco, Cal.

Oil Circuit Breakers.—Bulletin L20360, 4 pp. Describes the new Westinghouse type FO-24 breaker, designed specifically for outdoor service, and available in single-throw two- and three-pole construction, and in capacities of 400, 600 and 800 amperes for application to operating voltages of 15,000 or less. Motor, solenoid and manual-operated mechanisms, mounted directly on the frame or pole unit and enclosed in weather proof housings, are applicable to all ampere capacities and pole sizes of the breaker. Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Live Circuit Indicator.—Bulletin 130, 4 pp. Describes the new Minerallac Statiscope for the protection of the electrical worker and designed to give positive indication of alternating current potentials of 2300 volts and up. It is a glow-tube form of electroscope encased in hard rubber about the size of a fountain pen. When placed in proximity to any live conductor a glow will appear in the little window directly over the tube indicating the presence of potential. At 2300 volts it will operate at a distance of approximately eight inches, and at 16,000 volts at a distance of about 36 inches. It is thus possible to approximate the voltage of the conductor being tested. It will also operate on lower potentials than 2300 volts by decreasing the distance between the conductor and instrument. Minerallac Electric Company, 25 No. Peoria Street, Chicago, Ill.

NOTES OF THE INDUSTRY

Increased Prices on Fuseswitches.—The W. N. Matthews Corporation, 3706 Forest Park Boulevard, St. Louis, Mo., announces an increase in prices on open type Matthews Fusswitches, made necessary because of the increase in materials. An increase has also been made on the company's Scrulix anchors. Revised price sheets are ready for distribution.

Underground Cable Boxes With Air Valves.—The G. & W. Electric Specialty Company, 7780 Dante Avenue, Chicago, Ill., are now supplying their underground cable boxes with air valves to supplement tests made at factory. These valves are similar in size to those on automobile tires. The valves are used for testing subway boxes for air tightness after boxes have been installed in manholes and after boxes have been opened and again reclosed. All that is necessary for making the air test is an ordinary automobile air pump and a low pressure gauge.

New Sunshine Carbon Arc Lamp.—An addition to the widely known "Eveready" family in the form of a product that, incidentally, will open a new field to the central station for merchandising of off-peak current, soon will be announced by the National Carbon Company, Inc., Cleveland, Ohio. Besides developing several special types of therapeutic carbons for the use of physicians and hospitals for their particular work in light therapy, the company has also perfected two new products, namely, "Eveready" sunshine carbons and "Eveready" sunshine carbon arc lamps. An almost unlimited market is anticipated, as the subject of sunlight and ultra violet rays has a unique and widespread appeal. It is understood that the new lamp will be introduced to the public through a national campaign of advertising.

Largest Installation of Supervisory Control Equipment.—The largest single supervisory control equipment in the world is now being assembled for the New York Edison Company, according to the Westinghouse Electric & Manufacturing Company at East Pittsburgh, Pa. The equipment will be installed in New York City to control the Riverside Substation at 238th Street from a dispatching office located in the 188th Street Station.

The supervisory equipment is of the synchronous visual type and is entirely mounted on standard steel switchboard panels. The equipment is arranged to ultimately control and supervise 115 pieces of apparatus, supervise only, 43 pieces of apparatus and indicate 95 selective remote meter readings. The apparatus controlled consists of high and low tension breakers, bus tie and bus grounding breakers, feeder breakers, voltage regulators, blower motors and battery charging m. g. sets. Supervision only of transformer temperatures, live lines, battery voltages, potential transformer fuses, battery and bus ground detectors, station service automatic transfer switch and substation door is provided.

New Cooling System Increases Capacity of Electrical Equipment.—It is claimed that up to 50 per cent more power can be handled by the same size electrical apparatus equipped with a new system of cooling introduced by the General Electric Company. Use of hydrogen gas within a totally-enclosed rotating machine has made this possible without increasing the operating temperature beyond the point of safety.

The first commercial application of the new system of hydrogen cooling has been made with a synchronous condenser installed by the New England Power Company at its Pawtucket, R. I., substation. If the condenser were air-cooled, as are all other condensers today, its capacity would be 10,000 kilovolt-amperes; but by having it hydrogen-cooled its capacity has been increased to 12,500 kilovolt-amperes. With hydrogen at 15 pounds per square inch gauge pressure, the machine could deliver 15,000 kilovolt-amperes without exceeding the normal temperature guarantees, according to General Electric engineers.

The advantages of hydrogen cooling are numerous. Not only is the capacity increased for a given size of machine, but oxygen and dirt are excluded by the air-tight casing. Hydrogen will not support combustion, and fires of any kind—even from short circuits—are consequently impossible. Hydrogen also eliminates the effect of corona on the insulation. The usual air-cooled machine must be placed within a building; but the hydrogen-cooled equipment, being totally enclosed can be placed outdoors, with a resultant saving in building cost.